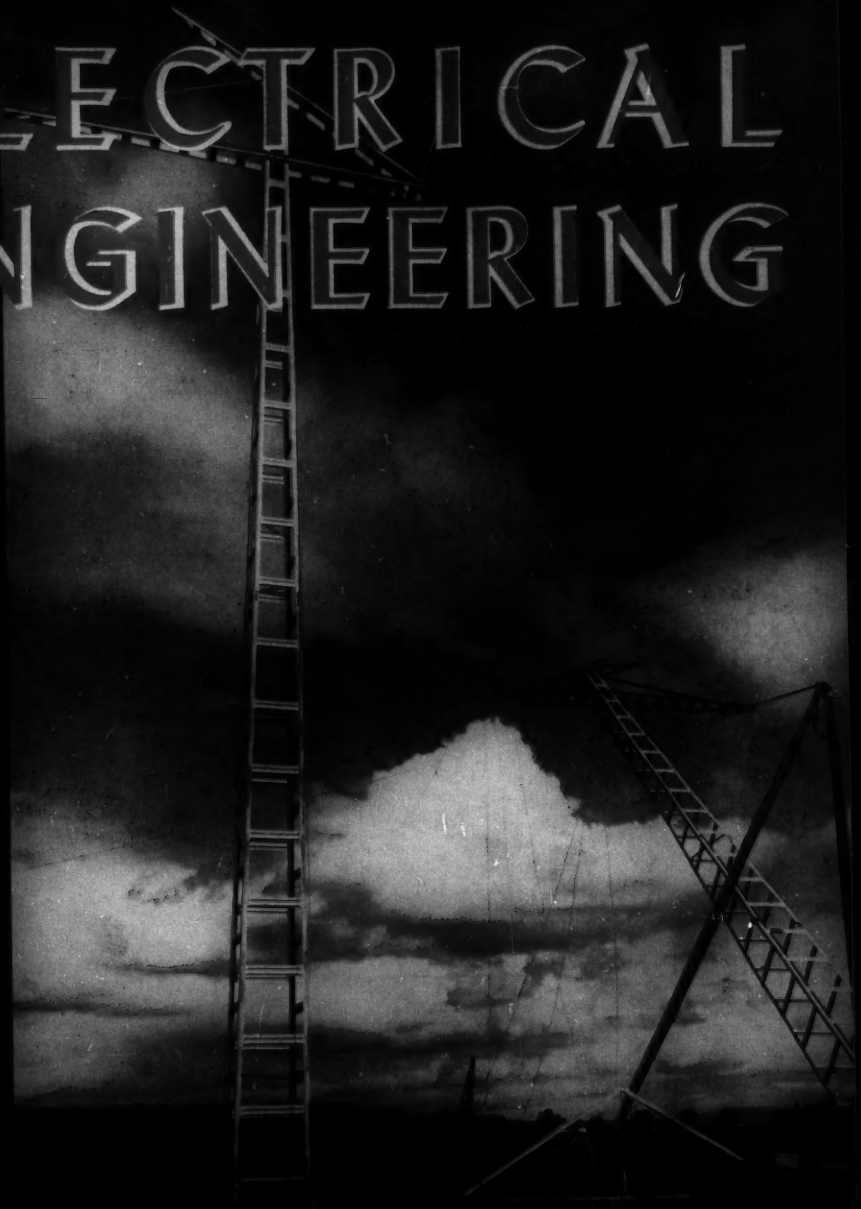
ELECTRICAL ENGINEERING

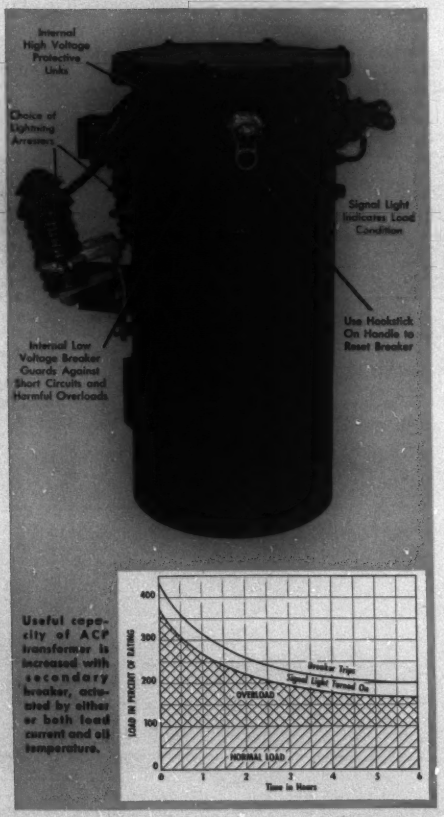


DECEMBER

1949

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

HERE'S *Premium* TRANSFORMER PROTECTION



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DECEMBER
1949

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GENERAL ELECTRIC

HIGHLIGHTS .....

Professional Unity. Outlining a program to promote professional unity among engineers, James F. Fairman suggests that the project start in colleges. Cooperation among the student members of various engineering societies should be encouraged by fostering one over-all engineering society, and practicing engineers should help give the students a better understanding of what it means to be a member of the profession (*pages 1027–3*). To study further the subject of increased unity for engineers, an exploratory meeting was held on October 20 at the invitation of Engineers Joint Council and participated in by representatives of the leading engineering societies of the country. As a result of the discussion, a Planning Committee was appointed from members of the group (*page 1110*).

Winter General Meeting. With headquarters in New York City's Hotel Statler, the AIEE Winter General Meeting for 1950 is scheduled to run from January 30 through February 3. As usual, this popular meeting will feature a comprehensive technical program, a number of interesting inspection trips, and a full roster of entertainment events (*page 1099*).

Power Conference Scheduled. Announcement has been made of the first Special Technical Conference to be sponsored by committees within the Power Group. With power generation and industrial power systems as the subject, it will be held in Pittsburgh, Pa., in April 1950 (*page 1105*).

Fall General Meeting. Featuring several technical sessions on subjects not heretofore included on AIEE meeting programs, the 1949 Fall General Meeting was held in Cincinnati, Ohio, October 17–21. An interesting schedule of inspection trips and entertainment rounded out an enjoyable week for the members in attendance and their guests (*pages 1100–03*). As usual, the technical program for the meeting included a number of conference papers which are digested briefly in this issue, inasmuch as these papers will not appear in AIEE *Transactions* or AIEE *Proceedings* (*pages 1091–8*).

Swedish 380-Kv System. The water power resources and population concentration in Sweden are widely separated, and in order to make full use of the resources available, Swedish engineers are planning a 380-kv system to transmit the power to the consumers. An account of design problems encountered is told by the president and chief engineer of the Swedish State Power Board (*pages 1025–29*).

Conductivity in Semiconductors. The nature of conductivity in semiconductors, including nucleon-bombarded and oxide semiconductors, is considered in the third article of a series on electrical properties of semiconductors and the transistor. The original papers were presented at a symposium on the subject at the Summer General Meeting (*pages 1047–56*).

Electric Instrument Calibration. All types of measuring instruments now in use can be calibrated by the three self-contained equipments described by this author. One of these units calibrates most common d-c instruments; the second unit is a d-c dual potentiometer standards equipment. Calibration of a-c instruments is accomplished with the third unit (*pages 1065–6*).

Power for Television Receivers. Unlike a radio, a home television receiver requires both a relatively complex low-voltage B+ and bias supply and a high-voltage power supply. The current requirements of the latter range from 100 to 600 microamperes, thus presenting special design problems (*pages 1061–5*).

Quality Control. What is new about quality control? What is a quality control program? Is quality control good only for mass production? These are a few of the questions which are considered in this discussion of quality control as a method of management (*pages 1069–73*).

Conductive Flooring for Hospitals. Because static electricity has been identified as one of the chief dangers which must be overcome in the design and construction of hospitals, the use of conductive flooring in such structures is now generally accepted. Test results are presented on two materials which are believed to meet necessary qualifications at comparatively low cost (*pages 1085–90*).

Magnetic Ferrites. Because of their low electrical conduction, and therefore low eddy current losses at higher frequencies, the magnetic ferrites find their greatest usefulness at communications frequencies. Here, real advantages in performance and space saving are to be had in inductors, transformers, and so forth (*pages 1077–80*).

Industrial Electronic Problems. One of the difficulties facing a teacher of engineering is to invent problems for his students which will approximate the problems that they will meet later in the profession. A good source of material, however, can be the practical problems actually encountered in engineering work. Problems such as these, diligently worked out by the student, not only will present the new subject, but will call upon his knowledge of subjects previously presented in his course (*pages 1041–3*).

Growth of West Coast Telephone Service. Since 1915, when transcontinental telephone service was first established, the Pacific Coast area has tripled its population and increased sevenfold in number of telephones and thirtyfold in toll circuit mileage. How West Coast utilities have kept up with the continually growing demand for telephone service is described comprehensively in this article (*pages 1033–8*).

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AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec 46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
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Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General

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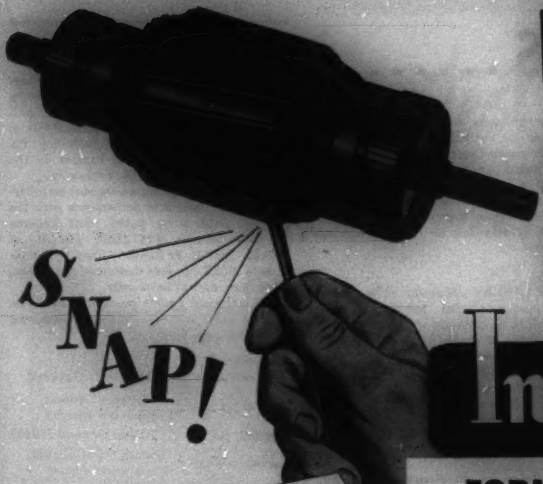

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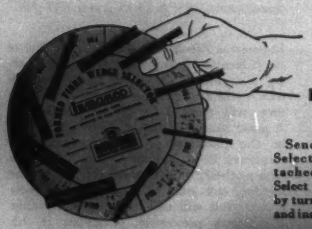

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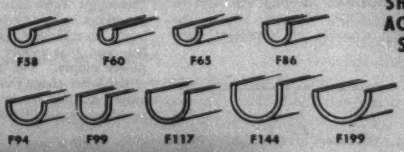

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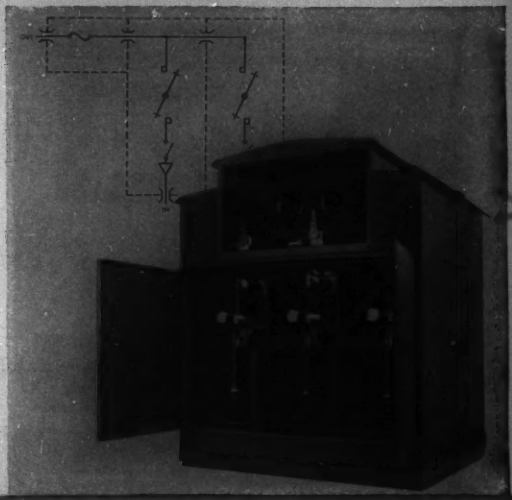

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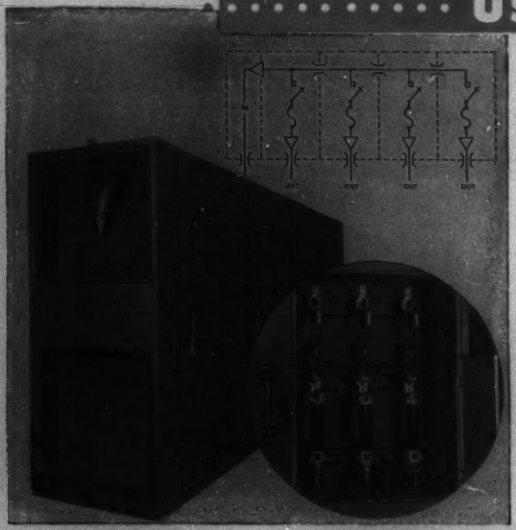

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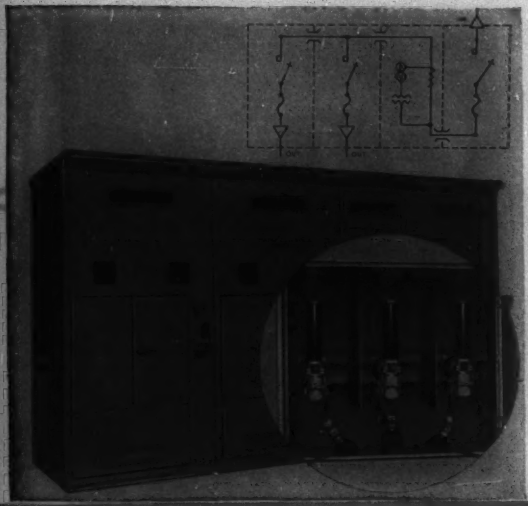

Typical Performance Characteristics of S&C Metal-Enclosed Switchgear Units:

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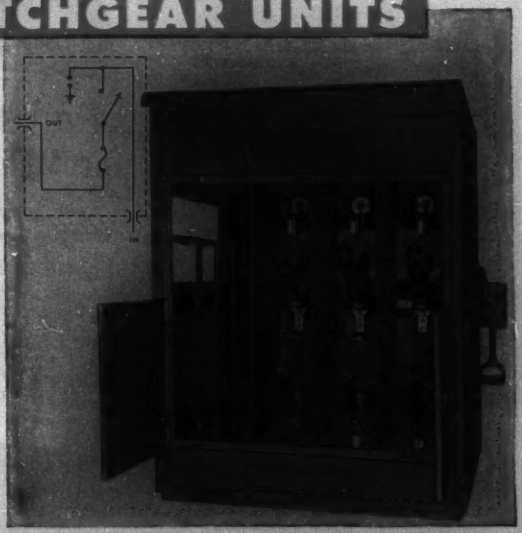

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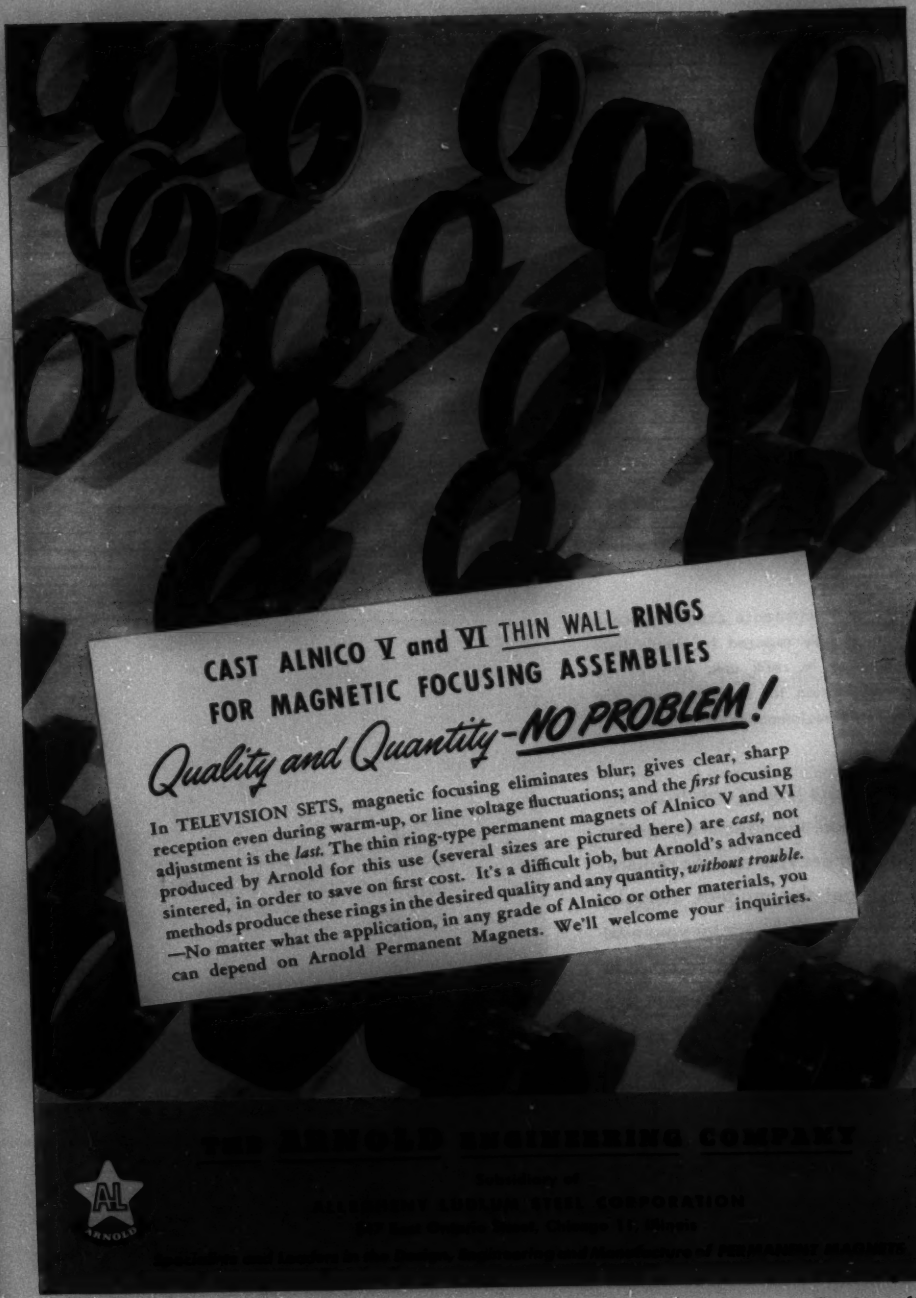
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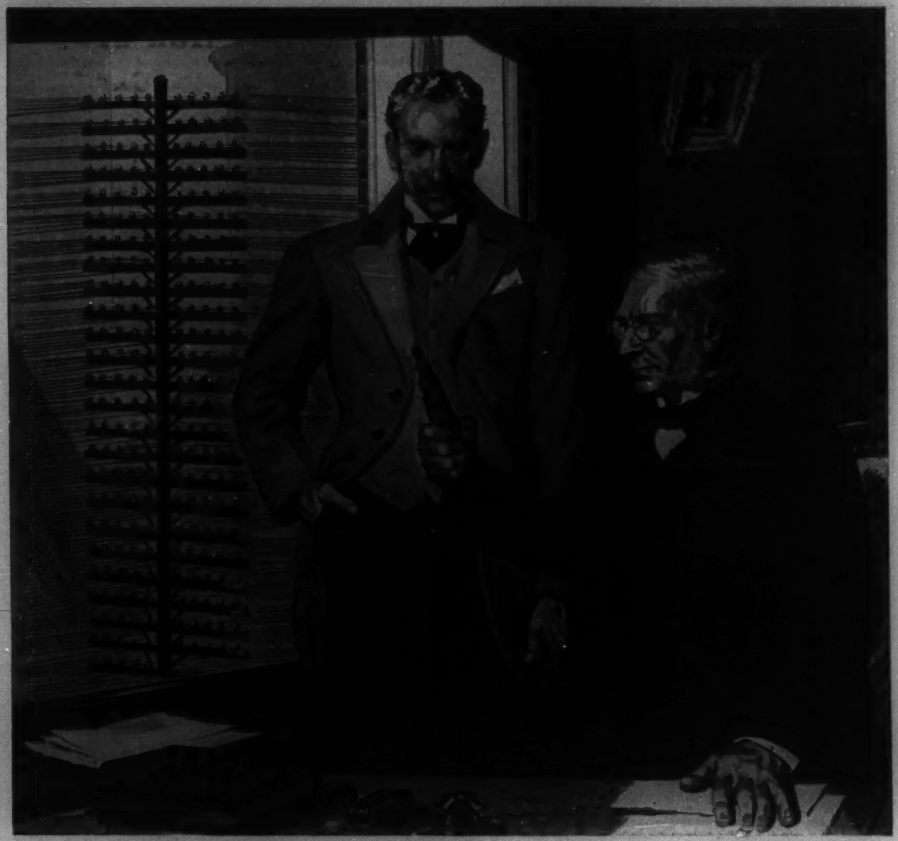

They Packed a Pole Line Into a Pipe

Back in the eighties, telephone executives faced a dilemma. The public demanded more telephone service. But too often, overloaded telephone poles just couldn't carry the extra wires needed, and in cities there was no room for extra poles. Could wires be packed away in cables underground?

Yes, but in those days wires in cables were only fair conductors of voice vibrations, good only for very short distances. Gradually cables were improved; soon every city call could travel underground; by the early 1900's even cities far apart could be linked by cable.

Then Bell scientists went on to devise ways to get more service out of the wires. They evolved carrier systems which transmit 3, 12, or even 15 voices over a pair of long distance wires. A coaxial cable can carry 1800 conversations or six television pictures. This is another product of the centralized research that means still better service for you in the future.

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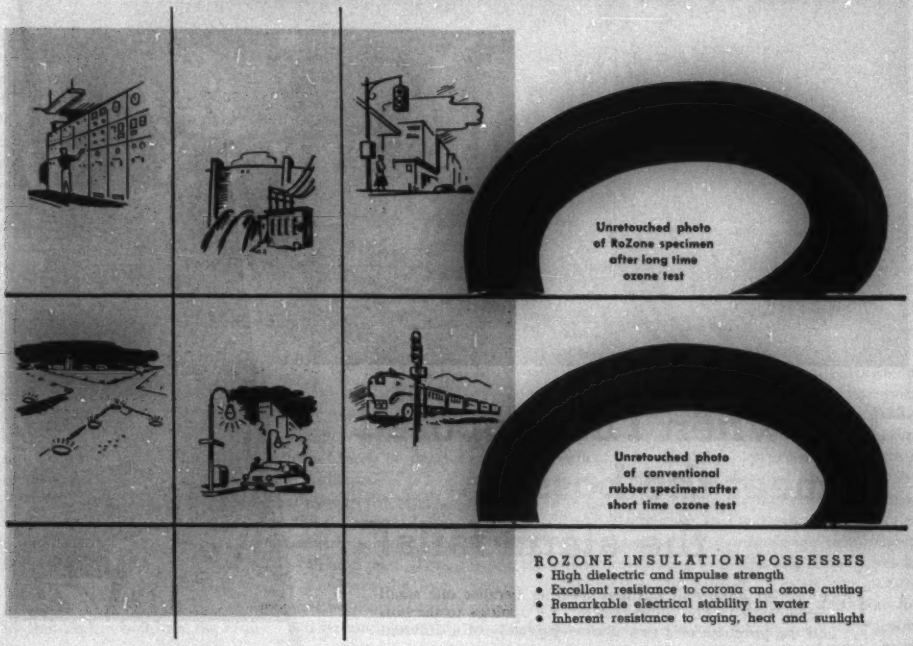
Unretouched photo of RoZone specimen after long time ozone test
Unretouched photo of conventional rubber specimen after short time ozone test

ROZONE INSULATION POSSESSES

- High dielectric and impulse strength
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UNITED STATES STEEL

Professional Unity at the Grass Roots

JAMES F. FAIRMAN
PRESIDENT AIEE

ON MANY previous occasions we have used the term "grass roots" in our discussions of Institute activities. Probably when the term is used you assume, as I do, that it refers to the local units of national organizations such as our Sections, or to the individual members. Using the term in connection with professional unity serves to reinforce this idea of what we mean by "grass roots" because efforts have been made to encourage joint activity among local units on local problems in the hope that out of such co-operation there would evolve a better method of handling common problems at the national level of those organizations. In certain instances the results locally have been so encouraging that it is difficult for the members involved to understand why greater progress is not made at the national level. The evidence is largely negative but I suspect that part of the reason for the difficulty is due to the lack of a clear indication of interest on the part of the individual members in problems at the national level and of their wish that more be done by their national societies about those problems.

Here President Fairman applies the term "grass roots" to the students in the engineering schools who are the future members of the profession. Courses of individual and group action which would benefit the students, the schools, the employers, and the profession are proposed.

But that is not what I shall discuss with you in this article. When I use the term "grass roots" in this discussion, I am thinking of the students in the engineering schools, the future members of the engineering profession and of its several organizations. I suggest that these are the true grass roots and that it is among them that we should begin to plan and to build for the future. To be sure, many of our engineering societies have student memberships and encourage the organization and support the work of student branches or chapters at the engineering schools. The societies have done and are doing an excellent job of promoting the technical development of students in their respective specialized fields. This work should be continued, nurtured, and constantly improved but it does not cover the whole of their interest in and responsibility to the students. There are other and equally important needs for which less adequate provision has been made. Moreover, the existence of distinct curricula in the major branches of engineering and the establishment of separate student organizations by the several national engineering societies has had a perfectly natural, though I think unfortunate, tendency to emphasize the division rather than the essential unity of the engineering profession. Also, in spite of these evidences of our altruistic interest in the students as future members of the profession it sometimes seems that we are more concerned about enlisting them as future members of our several organizations and that more effort is directed toward using the student branches as recruiting agencies rather than as a means of supplementing the formal education of the students with information and points of view which would better prepare them for entrance into a profession.

Full text of an address presented at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949.

James F. Fairman is Vice-President, Consolidated Edison Company of New York, Inc., New York, N. Y.

PROPOSED GROUP ACTION

Let me be specific as to some of the things that we might do as individuals and as organizations interested in the problem. As national organizations, if we really believe in the unity of the engineering profession and that it may be desirable to have some over-all organization as an expression of that unity, why not start by encouraging the establishment of a single student engineering society at each engineering school. By all means, let us keep the existing student branches or chapters as technical divisions of the student society but let us not hamper them by a lot of rules and regulations. Rather, let us use them as laboratories in which to experiment. Let us encourage membership in the student society among freshmen and sophomores as well as among juniors and seniors. Let us continue to offer student membership in our national organizations for nominal dues to any student who desires it for the purpose of obtaining the publications of one or more of the societies.

Let us accept for the next higher grade of membership in a national organization, without admission or transfer fee within a reasonable time after graduation, any student who was a member of the student engineering society, whether or not he was a student member of one of the national societies. That should suffice for recruiting purposes. Then let us tackle the real job of helping the faculties give the students a better understanding of what it means to be a member of a profession.

PROPOSED INDIVIDUAL ACTION

How should we go about this? Here is where individuals as well as local groups can be most helpful. Student organizations like most other organizations want speakers for their meetings. They could be encouraged to invite and I believe they would welcome speakers who would tell them something about the facts of life after graduation. In the process of telling that story we should have a wonderful opportunity, without laboring the point, to supplement

what they may have been told in the classroom about the necessity of using the written and spoken word effectively and the fact that their education is a continuing process. We could get across to them the concept of engineering as a co-operative enterprise and hence the necessity of give and take in practical everyday affairs. We might convince them that a great deal of their future success will depend upon their ability to get along with other people. A discussion of getting along with other people could introduce the concept of professional ethics, but we don't have to scare them off by using that term as the announced subject of our remarks. It also involves the idea of the individual's obligation to serve his profession and society, and incidentally himself, by using the mechanism of organization for the exchange of information and experience and for the attainment of specific objectives. By our own attitude we may best demonstrate the real satisfaction which results from sharing our experiences and serving our profession. We may even be able to convince them that the more tangible returns are usually in proportion to the value of the individual's contributions to society and that mahogony desks are not passed out with diplomas but come as a result of demonstrated ability.

James F. Fairman

Then there are inspection trips. These are always welcomed by student organizations. Here is another opportunity not only for giving the students a glimpse of the engineering world outside academic walls but of talking to them briefly, individually or as a group, about engineering as a profession under circumstances which might find them in a particularly receptive mood.

SUMMER EMPLOYMENT AND STUDENT GUIDANCE

Summer employment, if properly handled, can be mutually advantageous to the students and to the employer. I shall touch on only that aspect which is pertinent to my thesis. The student should not be given some routine job and forgotten. Some engineer who is interested in what we are trying to do and who is competent to do it should be assigned as the student's counselor. He should explain the company's operations and how the individual's work fits into the scheme of things. He should answer questions. He should encourage discussion on all sorts of problems, technical, economic, social, and political. A good time and place for such discussions is after dinner in the counselor's home.

Conferences with individual students at our own places of business might logically develop from these initial contacts. The possibilities here are tremendous. It would take some of our time but if enough of us would work at it, it should not be an excessive burden on anyone. And it would be a convincing demonstration of our belief in the gospel we would be attempting to spread.

Some of us do some of these things more or less sporadically and on request. My point is, we should seek more opportunities of this kind to serve the profession of the future and thereby to discharge part of our own obligation to the profession of the past. Many of us have been too prone to blame colleges for the shortcomings of the educational product. We have criticized, sometimes constructively, but we have not done as much as we might have to assist the faculties in preparing students for their future careers. We need not wait on organization for these opportunities. The opportunities exist. Let's take advantage of them individually.

ACCENT ON UNITY

In all of this effort, I suggest that our emphasis should be on the oneness of the profession, not only on the fact that our approach to problems, our method of attack, our processes of analysis, our fundamental technology are something we hold in common, but that our problems in the social, economic, and political fields, resulting from our own technological achievements or from external factors, are matters to which the attention of a united profession should be directed. We can arouse the students' interest in those problems and challenge the students to handle them more effectively than we have in our generation.

There has been a great deal of discussion about the content of engineering curricula and the number of years of formal education required properly to prepare the student for an engineering career. I do not intend to go into this matter except to suggest that I think a great deal of confusion is due to the fact that we practicing engineers have not given a clear and considered expression of our opinion to the schools.

For example, on the one hand some of us maintain that we want sound training in the fundamentals at the expense of specialization; on the other hand some of us say that we want the graduate to be of immediate use to us in our particular business. I wonder if we ourselves are not confused as to the distinction between the engineer and the technician, between an individual having a professional outlook and one possessing only a specialized skill. There is need for both types of people but I submit there is a vast difference in the training that each should receive. I suspect that many technicians leave our schools under the impression that they have been trained to be engineers and are disappointed when they find it difficult to obtain or hold positions of truly professional caliber. Conversely graduates with adequate professional preparation are understandably unhappy in positions requiring only technical skill. It should be helpful to all concerned, faculties, students, and employers, if we could make some reasonably satisfactory distinction and by proper selection, guidance,

and education, prepare individuals for the career to which they are best suited. By taking a more active interest in this problem as an obligation which we owe to our profession and to society, perhaps we may arrive at a time when the profession will determine the desirable content and duration of an engineering education.

OUR OPPORTUNITY

This problem of engineering education is not my main theme. I mention it as part of the larger problem, one about which we should be doing something more constructive than we have in the past. The point of my remarks is that we have a tremendous opportunity to foster professional unity at the grass roots by working with the engineering students and by our attitude, as individuals and as organizations, indicating that engineering is more than technology, that it is a profession, and that it is one profession in spite of appearances to the contrary.

As many of you are aware, the Institute, in co-operation with the Institute of Radio Engineers, took a tentative step in this direction in 1946 by providing for the establishment of joint student branches and went on record as being willing to try a similar arrangement with other national engineering societies. Recently, the American Society of Civil Engineers invited representatives of a number of national engineering societies to a conference on the problem. The AIEE was represented by the chairman of the Committee on Student Branches, Director F. O. McMillan. The first meeting, held on September 12, was necessarily only exploratory. A second meeting is tentatively scheduled for January. Probably a number of meetings will be required before the conference can produce definite proposals for the consideration of the several societies represented.

I shall offer these proposals for their consideration as I offer them for yours. You and they may disagree with me on the method but I am confident we all agree on the objective. I, for one, believe that it is high time for a venture of faith. But regardless of what we may do as national organizations, let us as individuals and as local groups, show our faith in the future of our profession by our works among the next generation of engineers.

Oklahoma Utility Operates Gas Turbine Power Plant

One of the first central station installations of the gas turbine in the United States has been made by the Oklahoma Gas and Electric Company at its Arthur S. Huey Station. This General Electric 3,500-kw simple-cycled gas turbine power plant, in over 1,500 operating hours, has produced approximately 5¼ kilowatt-hours, averaging 3,557 kw.

The new turbine was put on the line on July 28. According to an official of the Oklahoma utility, the gas turbine, on September 28, permitted a pickup in total station output from 51,000 to 58,000 kw with an over-all improvement in plant operating economy. Of this pickup, the gas turbine carried approximately 4,000 kw and the balance of 3,000 kw was achieved in plant operation. Prior to installation of the new turbine, the Huey Station had a rated capability of 56,000 kw, but limitations in maximum heat input to boilers produced a capability of only 51,000 kw.

The new gas-fired unit is installed in a building added to one side of the existing plant. The building has a standard crane and power hoist operated from the floor. A large door allows trucking or dollying any part of the equipment into the main plant machine shop.

The weight of the complete power plant including the compressor and gas turbine is only 25,000 pounds. The complete unit, including the generator and exciter is less than 50 feet long and nine feet wide, and located all on the same floor level with the exception of the oil tank. The foundation loading is low, carrying a total of only 85,000 pounds. Seen in the illustration is an interior view of Huey Station from the compressor end, showing air intake, gas turbine, exhaust to heat exchanger, and, in the rear, the load end of the gas turbine power plant.

Operating on natural gas, the turbine makes available more total power than that which it generates itself. The waste heat from the exhaust is used with a separate heat exchanger to supplement the present boiler feed water heating system. By supplementing the heating capacity of the installed equipment, better use is made of the available turbine shaft capacity of the steam generating units.

Automatic Switches to Protect Transformers

E. A. RICKER
MEMBER AIEE

AN AUTOMATIC grounding switch in combination with an automatic air-break switch can be used in place of a circuit breaker in the 110-kv supply to a transformer. Since internal faults in transformers do not occur frequently, these high-voltage circuit breakers can be put to better use at terminals of transmission lines where faults are caused by lightning. The substitute for a circuit breaker on the high-voltage side of a transformer must provide for interrupting load, magnetizing, and fault currents. The low-voltage circuit breakers are necessary in all except very small single-bank stations for all three interrupting duties. An air-break switch on the high-voltage side of a transformer should be able to interrupt the magnetizing current or to break parallel in a station having two or three banks of transformers. The remaining duty is to interrupt current flowing from the 110-kv network into a faulted transformer. This can be done indirectly by putting a fault on the 110-kv bus which will operate circuit breakers at distant ends of the 110-kv transmission line. This is a drastic method of avoiding interruption of 110-kv fault current at the station flowing to transformer with an internal fault; but as this kind of fault occurs very seldom, such a general interruption can be endured occasionally. When two or more transmission lines are terminated at such stations, high-voltage circuit breakers are required at terminals of lines only, because the automatic air-break switch can be used to disconnect a faulted transformer after all sources of fault current have been removed.

In transformer stations having a single infeed for normal operation no high-voltage breaker is required. An automatic grounding switch can be tripped by relays which protect a transformer, thereby putting a line-to-ground fault on the 110-kv line which is detected by ground relays at distant ends of the line and the circuit breakers are tripped. A pallet switch on the automatic grounding switch controls the automatic air-break switch, but a timer is used in the circuit to delay the opening of the air-break switch until the distant circuit breakers have had time to interrupt the fault current.

The first two installations, made in 1930 and 1932, had a counterweight on the arm of one phase of the grounding switch to supply the force to close it.

An analysis of troubles shows that the lack of sufficient stored energy was the cause of many mechanical failures. The original installations operated satisfactorily, but exposure to the weather caused corrosion and misalignment, thereby reducing the extra stored energy. Failures in control circuits occured in 45 per cent of the troubles, some of them due to insufficient voltage to operate the tripping latch. The station battery should be at least 48 volts and preferably 125 volts, to eliminate trouble from contact resistance. The higher voltage permits installation of motor-operated mechanisms for opening and closing automatic air-break switches.

Routine tests would eliminate nearly all failures in service. Exercising the mechanism would detect any loss of adjustment in pallet switches, or excess friction in bearings caused by misalignment, and would keep the contacts clean by the wiping action. The tests should be a complete check on the combination of switches and control circuits from the time a contact is closed at the switchboard until the air-break switch has moved to the open position.

Diagrams of early installations are shown in Figure 1. Tests could not be made without removing the 110-kv line from service; other tapped stations fed from the same high-voltage line were interrupted during the tests. Diagrams for recent installations are shown in Figure 2. The apparatus has been rearranged, and other manually-operated disconnecting switches have been added. Low-voltage circuits at these tapped stations should include breakers and switches for transferring load to other stations, so that tests can be made during light load periods.

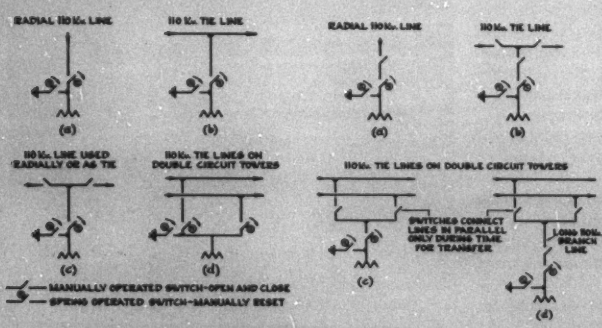

Figure 1 (left). Small transformer stations without 110-kv circuit breakers

Testing interrupts service

Figure 2 (right). Modifications which permit easy testing of automatic switches

Digest of paper 49-143, "Automatic Grounding and Air-Break Switches for Protection of Transformer Stations," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

E. A. Ricker is with the Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada.

The Swedish 380-Kv System

ÅKE RUSCK BO G. RATHSMAN

In order to transmit power efficiently from its source in the northern part of Sweden to the consumers in the southern part of the country, Swedish engineers have started construction on a 380-kv transmission system.

BIG POWER PLANTS are at present under construction in the north of Sweden. Since the consuming centers are situated in the middle and south of Sweden, transmission of still greater amounts of energy is necessary. The existing 220-kv lines are insufficient for this purpose. In order to get a transmission system of greater capacity than that of the 220-kv lines, it has been decided to complete these with 380-kv lines. The article describes the first stage of construction of the 380-kv system with one line, 600 miles long, and deals with the special problems brought about by the high-voltage of the system.

Sweden has a population of seven million people, that is, 5 per cent of the population of the United States. The area is somewhat bigger than that of California. Sweden is rather long-stretched. The distance from the northernmost to the southernmost point is about 1,000 miles or nearly the same as the distance between the Canadian and the Mexican frontiers. The country is situated rather far to the north and one part of it reaches north of the Artic Circle.

Sweden has no coal and no oil, but the water power resources are quite big. When utilized they will give an annual output of about 7,000 kilowatt-hours per inhabitant. When the present construction program is ready in five years, the annual output will be 21,000 million kilowatt-hours or 3,000 kilowatt-hours per inhabitant, which means that 40 per cent of the water power which is available will be utilized.

About 85 per cent of the power resources are situated in the north and 15 per cent in the southern parts of the country, whereas the distribution of the population, and hence of the power demand, is the reverse.

The increasing demand for electric power must be met by progressive development of the sources in the north. Figure 1 shows the necessary energy transport from the north to the south of Sweden. The left figure is the stage reached by the middle of the 1950's and the right diagram is the ultimate stage in 30 to 40 years, when all waterfalls will be harnessed. The transmission distances amount to between 300 and 600 miles. The development of the transmission technique is an essential condition for the utilization of the Swedish water power.

At present the power is transmitted from a district situated in the middle of Sweden, about 300 miles north of the capital, Stockholm, to the southern part of the country over six 220-kv lines. Figure 2 shows the Swedish 220- and 132-kv transmission line system. The total line length of the 220-kv network is about 2,500 miles. The new 380-kv line is shown by a thick, continuous line.

The main part of the 220-kv network is owned by the State Power Board, which is the biggest power enterprise and has about 40 per cent of the production and distribution of electric power. The rest of the production and distribution is handled by a comparatively great number of private and municipal undertakings, but all power plants are jointly operated.

The postwar development program indicated a rate of increase in power consumption which within a few years would entail adding 300 miles of new 220-kv line each year. The alternative solution of employing a system with greater transmission capacity had to be considered seriously. The decision in 1946 to harness Sweden's biggest waterfall, Harsprånget, enhanced the urgency of the matter. This waterfall is situated 22 miles north of the Arctic Circle, and the power must be transported 600 miles to the consumer center. The possibility of using high-voltage direct current was considered, but it was evident that the development of the d-c system would not progress sufficiently rapidly. Investigations were therefore confined to the use of a-c transmission at voltages above 220 kv, and after carefully comparing the relative merits of voltages of 220,

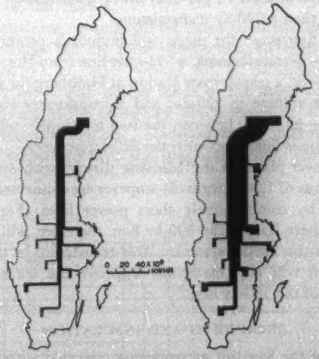

Figure 1. Projected development of the Swedish power transmission system

Left: To be completed by 1955 Right: Ultimate stage

Essentially full text of a conference paper, "The Swedish 380-Kv System," presented at the AIEE Pacific General Meeting, San Francisco, Calif., August 23–26, 1949.

Åke Rusck is President and **Bo G. Rathsman** is Chief Engineer of the Swedish State Power Board, Stockholm, Sweden.

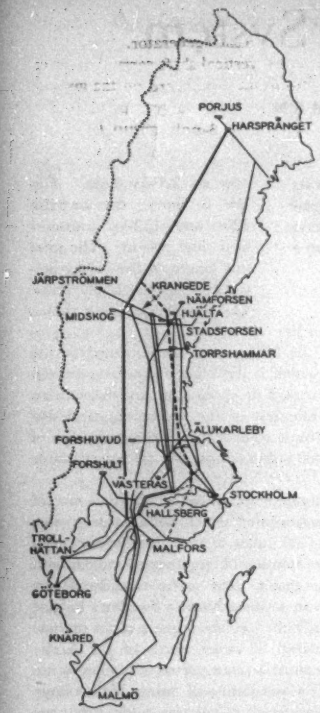

Figure 2. Existing 220- and 132-kv lines and the new 380-kv lines

330, 380, and 440 kv, it was decided in December 1946, to use a 380-kv line. Later the voltage level was defined in such a manner that the maximum service voltage was fixed at 400 kv. It was found that a 380-kv transmission would give at least 15 per cent lower transmission cost per kilowatt than a 220-kv transmission.

In its first stage the plant will include a power station with step-up transformers, a 593-mile line from Harsprånget to Hallsberg, a transformer station at Hallsberg for stepping down the voltage to 220-kv, and a transformer station at Midskog—half-way between the two terminals—where the 380-kv line is linked up with the 220-kv network. A number of power plants in the Midskog district with an aggregate output of 1,200 megavolt-amperes are connected to this network by comparatively short power lines (Figure 3). The southern half of the 380-kv line, therefore, will be able to relieve the 220-kv system. This connection to the 220-kv system will also materially improve the transmission capacity of the 380-kv line.

GROUNDING AND INSULATION

Most of the Swedish networks are operated with neutral grounding through Petersen coils. At the 380-kv system, the heavy additional expense incurred by the use of Petersen coils and the complication of the transformer design that it entails, made it preferable to choose a solidly grounded neutral instead.

For the station insulation an impulse withstand voltage of 1,775 kv on 1/50 full wave will be used. This is rather high for a solidly grounded system. There are, however, certain complications. Owing to the excessively long transmission lines, the system will be subjected to exceptionally high voltages when a loaded line is opened in one end. At single-phase faults, the voltage to ground at the open end of the line may exceed 200 per cent of the normal value, while at the 380-kv bus-bars in the power station it may rise to about 180 per cent.

Besides, the transformer cost would decrease only about 7 per cent when choosing 14 per cent lower insulation level. This decrease was considered too slight to justify any attempted saving at the expense of insulation quality, especially as a high level would in any case be necessary for the switchgear equipment

The line insulation is governed by the requirement that

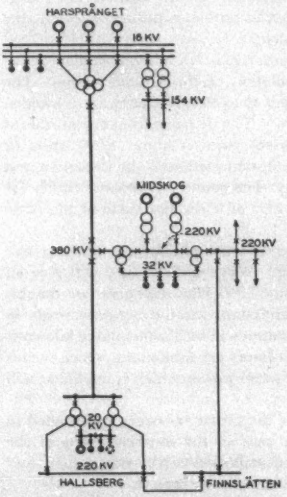

Figure 3. Line diagram showing first stage of the 380-kv system

it shall provide adequate safety against flashovers due to lightning or switching surges, and that the lowest line insulator elements shall not be subjected to excessive voltage stresses. A suspension string carrying 20 elements with a spacing of 6.7 inches, is the type most commonly used and has an impulse withstand strength of 1580 kv. This should give adequate security also if a few elements in the string are faulty.

POWER STATION AT HARSPRÅNGET

The power plant at Harsprånget will have a 4,700-foot stone-filled dam crossing the river at the power station site. The generator house is blasted into the living rock and has its floor 250 feet below ground level (Figure 4). After

passing the turbines, the water is discharged through a $1^3/_4$-mile tunnel, with a sectional area of 2,050 square feet. The rock excavated from the tunnel will be sufficient for nearly all the stone filling required for building the dam.

Three turbine sets will be installed, each rated at 3,800 cubic feet per second. The total head will be 350 feet, and the output about 300 megawatts. Space has been prepared for the future installation of a fourth set. The generators are rated at 105 megavolt-amperes, 16 kv. Because of the long-distance transmission, these machines are designed with low reactances. The subtransient reactance will be 15 per cent and the transient reactance 22 per cent. Auxiliary power requirements are supplied by 1,200-kva 50-cycle station generators which, in similarity with the exciters, are mounted directly on the generator shafts.

Bare conductors carry the generated power to the step-up transformers, likewise installed in the rock (Figure 5). The 16/380-kv transformer plant is of a special design (Figure 6) which has been found to present economic advantages. A bank of three single-phase transformers, each rated at 115 megavolt-amperes and equipped with a regulating transformer in the 380-kv neutral, is common to the three generators. A fourth set acts as a stand-by. The main transformers have five core limbs, the three central ones being equipped with separate 16-kv windings. By this construction it is possible to obviate excessive 16-kv operational and short-circuit currents. A 40-megavolt-amperes reactor is connected to each generator.

Cables running through a vertical shaft carry the power from the transformers up to the switchyard on the ground level. Six single-pole circuit breakers are provided for handling the 380-kv power, one 3-pole group being intended for normal service and the remaining poles for connecting the stand-by transformer and as a reserve for the service circuit breakers.

TRANSMISSION LINE

The line towers are of a type similar to that used for the 220-kv line (Figure 7). The standard span is 1,080 feet and the height of the cross beam above ground level is 75 feet. The clearance between phases is 39 feet.

High grade steel is used for the towers in order to keep down the weight. Masts and cross beams are built of angle iron joined by welded bracing pieces which are corrugated to give added stiffness. The towers are raised on a foundation consisting of 8 to 12 pieces of sleepers joined by heavy beams. To these beams are fixed two mast bases which reach up to ground level and carry the midsections and superstructure. All steel parts are hot galvanized; the lower sections are also dressed with zinc sheet as added protection against corrosion. On the cross beam are mounted two arms for supporting the steel ground wires. The standard construction of the towers weighs 7.1 tons, which corresponds to an average of 36.2 tons of steel per mile of line.

Double conductors are used, consisting of two steel-aluminum cables per phase, each with a diameter of $1^1/_4$ inches, that is an area of 1,170,000 circular mils per cable, corresponding to an equivalent copper area of 650,000 circular mils per cable. The two cables are suspended side by side, with a spacing of 18 inches.

The standard insulator string, comprising 20 elements, will have a total length of $13^3/_4$ feet (Figure 8). Single porcelain string insulators will be used for supporting a working load of up to four tons, which is adequate for 95 per cent of the towers.

The remaining towers will be fitted with two or more parallel strings but in most cases tempered high-tensile glass insulators in single strings will be sufficient. The strings are fitted with arcing horns at the upper end and a grading ring at the cable end which serves to equalize the voltage distribution. Standard cable holders, fixed to a yoke suspended from the insulator string, carry the

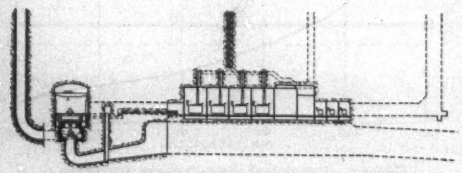

Figure 4. Section of the power station at Harspränget

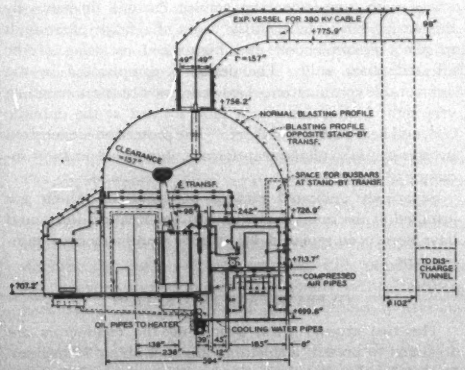

Figure 5. Section through the transformer hall at Harspränget power station

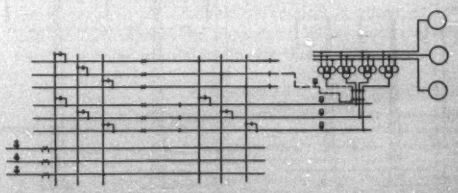

Figure 6. Connections for alternators, main transformers, and 380-kv switchgear at Harspränget

double conductor. The cables have armour rods and 12 vibration dampers per tower.

TRANSFORMER STATION AT HALLSBERG

The 380-kv line ends at Hallsberg, where the power is stepped down to 220 kv. Two transformer sets, together rated as 600 megavolt-amperes are installed. Each set is comprised of three single-phase units rated at 100 megavolt-amperes, and a 3-phase regulating transformer. Two shunt reactors of 60 megavolt-amperes each and a 75-megavolt-amperes hydrogen-cooled synchronous condenser are connected to 20 kv tertiary windings.

TRANSFORMER STATION AT MIDSKOG

The transformer station at Midskog serves to link up the midpoint of the 380-kv line with the 220-kv system.

Four single-phase 3-winding transformers will be installed, each with a regulating transformer in the 380-kv neutral. The transformer set is capable of transmitting 300 megawatts. Tertiary 30-kv windings will feed three shunt reactors of 60 megavolt-amperes each.

As the 380-kv Midskog-Hallsberg line will work in parallel with the existing 220-kv lines, the load will distribute itself largely in inverse proportion to the line reactances. It is, however, desirable to increase the proportion of the load transmitted on the 380-kv side in order to reduce losses. A phase shifting transformer is therefore installed on the 220-kv side at Midskog, giving a voltage displaced through 90 degrees and amounting to about 25 per cent of the main voltage.

CIRCUIT BREAKERS AND RELAY PROTECTION

In its initial stage, the 380-kv system will be equipped with seven air-blast circuit breakers rated at 1,000 amperes and having a rupturing capacity of 8,000 megavolt-amperes at 350 kv. These circuit breakers are to be equipped with nonlinear resistors in order to reduce the switching surges. The total breaking time is between four and five cycles. The circuit breaker design enables single- or 3-phase high-speed reclosing. The 220-kv circuit breakers will be of essentially similar design, having a rupturing capacity of 5,000 megavolt-amperes. Airblast circuit breakers will also be used for the lower voltages.

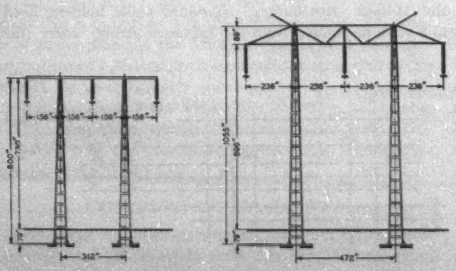

Figure 7. Line towers supporting double conductors for 220-kv and 380-kv systems

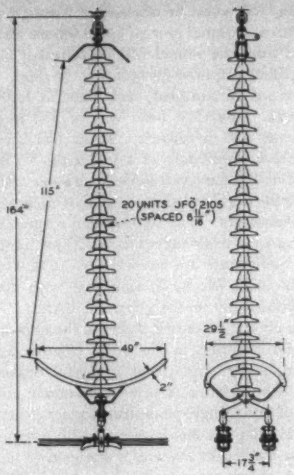

Figure 8. Insulator string with grading ring for 380-kv line

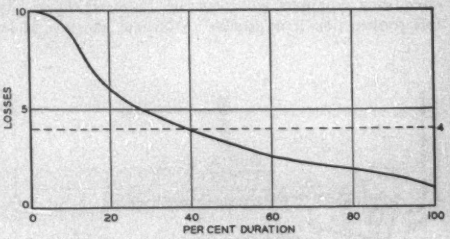

Figure 9. Duration of corona losses in 380-kv line

Relay protection for the lines is furnished by distance relays with supplementary carrier current devices. By this means it is possible in the event of a single-phase fault to effect disconnection and high-speed reclosing of the affected phase only. The design is complicated by the unfavorable combination of extreme line distances, entailing very light fault current at a fault located at the opposite end, and heavy service current. The protection is energized by a capacitor voltage transformer, connected to the conductor to be protected.

Separately mounted current transformers, which are installed at the main transformers, are a costly item, and have here been replaced by current transformers of bushing type.

OVERVOLTAGE PROTECTION

The two ground wires protecting the conductors are arranged to present a shielding angle of about 25 degrees. Each tower has its own ground cable system. The resistance to ground as measured by resistance bridge has been reduced to from 25 to 30 ohms. The entire line should

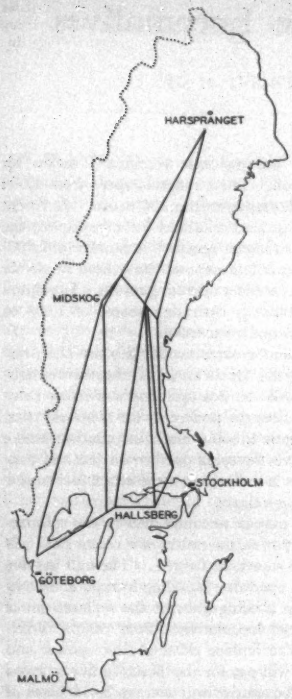

Figure 10. Preliminary principal diagram for future 380-kv system

then be subjected to an average of one or two lightning flashovers per year. Robust 380-kv surge arresters will be installed next to the cable boxes at Harsprånget. The switchyard is provided with a special ground wire protection which is also extended to cover the two adjacent spans of the 380-kv line. Surge arresters will also be installed at Midskog and Hallsberg. Both switchyards will be protected by ground wires strung to the towers, and grounding for the adjacent three miles of line will be carried out with exceptionally low ground resistance.

VOLTAGE CONTROL

Each line section generates 250 megavars at 380 kv. The heavy reactive power means that the load will appreciably affect the service voltage. However, various means are provided for selecting the voltage appropriate to service conditions, namely, the regulating transformers at the three stations, the eight reactors, totalling 420 megavars, the 75 megavolt-amperes synchronous condenser at Hallsberg, and linkage with the powerful 220-kv system at Midskog.

STABILITY, TRANSMISSION CAPACITY, AND LOSSES

Initially the north line section will only be used for transmitting power from Harsprånget, that is about 300 megawatts, which will give an ample stability margin. The section Midskog-Hallsberg, which will also receive considerable power from the 220-kv system, should, according to tests, be capable of transmitting about 400 megawatts without endangering the stability.

The ohmic losses in the north line section at 300 megawatts input will amount to 7.6 megawatts. The corresponding losses in the south section will be 13.6 megawatts when carrying 400 megawatts. To these must be added the corona losses, estimated at an annual average of about 4 megawatts for the whole line (Figure 9). The total line losses when transmitting maximum power will thus be about 25 megawatts during the first years.

TIME SCHEDULE AND COSTS

The first generator at Harsprånget is scheduled to come into operation at the beginning of 1951. By that time the Hallsberg-Harsprånget line should also be completed, but owing to delays in delivery of transformers and other equipment, the line will at first be operated at 220 kv. Towards the end of 1951 and the beginning of 1952 the other two generators at Harsprånget will be finished and this is the time scheduled for putting the 380-kv system into operation.

At present, the cost of the line is estimated at 25 million dollars, and that of the transformer stations at Harsprånget, Midskog, and Hallsberg at 11 million dollars. The cost of the power station at Harsprånget will be 28 million dollars. This gives a total cost for the entire system of about 64 million dollars. (The costs are converted at the rate for the dollar, current last summer, that is 1 dollar = Swedish crowns 3,60. The rate has since then been changed to 1 dollar = Swedish crowns 5,18.)

The construction of the power station at Harsprånget and the 380-kv line and transformer stations is being carried out by the State Power Board. Generators, transformers, circuit breakers, and remaining electric equipment will be supplied by the Swedish electrical firm, Allmänna Svenska Elektriska Aktiebolaget. The design of the 380-kv Harsprånget-Hallsberg system is the result of an intimate cooperation between this company and the board.

FUTURE EXTENSION OF THE 380-KV SYSTEM

The installation described will soon be followed by the extension necessary to provide transportation of power from new stations north of Midskog. A second 380-kv line to the south will be ready by 1953 (Figure 2, dashed thick line). This 300 miles line will be connected with the first line in a point 35 miles north of Midskog. Successive extension of the transmission system is then visualized up to the stage when all available hydro-electric power will be utilized. At present the number of 380-kv lines required for this purpose is estimated at six (Figure 10).

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The Preference for Diesel-Electric Locomotives

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DIESEL locomotives pulling long freight trains of several thousand tons on mainline railroads are a familiar sight, yet most people are not generally aware of the time and effort that must be expended in collecting and distributing this freight moving over the principal lines of the railways. The little known "work horse" that performs the seemingly thankless task of collecting and distributing this freight to all industries is the switching locomotive, working all hours of the day and night. Loaded cars are brought to a classifying point where further switching and transfer work is required to make up a through freight train destined for movement over the main line.

To meet the specific requirements of industrial service, there are many manufacturers who specialize in supplying industrial plants and railways with smaller switching locomotives, weighing 80 tons or less, with horsepower ratings up to 600. Main-line locomotives are much larger and have been built in capacities of 500 tons, and several thousand horsepower. These are specialized fields and usually are handled independently by different builders.

For many years the reciprocating steam locomotive handled practically all the transportation services in industrial plants. With the development of the diesel engine for railway vehicles it was recognized that this form of motive power was ideally suited for industrial switching service. Its success was due primarily to the electric transmission consisting of d-c propulsion generators and traction motors. The engine is a relatively constant-torque device and cannot meet the requirements of wide torque variation at the rims of the driving wheels without the introduction of a torque converting mechanism. The d-c generator and traction motors are unsurpassed as a torque converter. Locomotive builders have available reliable and efficient electric transmissions designed for the severe service encountered on industrial switching locomotive applications.

From the extensive application experience gained in the United States and abroad, there has evolved a line of standard units suitable for industrial work. These are classified by weight on drivers. The most common types are the 25-, 35-, 44-, 50-, 65-, and 80-ton locomotives. There is a sufficient degree of flexibility in design of these locomotives to permit builders to supply locomotives with characteristics to meet special operating requirements of users. And these special requirements are many. Both in this country and abroad, other than standard gauge is frequently encountered; also unusual width and height limitations are often imposed.

The builders of industrial locomotives do not manufacture diesel engines but purchase recognized makes for locomotive installation. These range in speed from 1,000 to 2,100 rpm and in horsepower from 100 to 600. In recent years, as engine design and reliability have improved, the trend has been toward higher speeds. A number of 2,100-rpm engines of 250 to 300 horsepower have been in service for several years with excellent operating results. In engines of 600-horsepower capacity operating speeds of 1,000 to 1,200 rpm are not normally exceeded.

Higher economy and greater availability are the principal factors sounding the "death knell" for the steam switching locomotive. Smoke-control ordinances of many communities merely increases the preference for diesel-electrics. Although some progress is being made in reducing smoke from steam locomotives by using overfire air jets and controlled combustion, it is unlikely that the steam locomotive will ever be as clean as a diesel.

To illustrate what may be accomplished by the substitution of diesel motive power, the results of a recent steel mill application study are shown in Table I. The mill has five steam locomotives in operation handling intraplant switching and consideration is being given to the replacement of these units with diesel locomotives. Four 50-ton diesel-electric locomotives can replace existing steam power and the resulting savings will pay for the diesels in five to seven years. Each diesel locomotive will average 3,415 hours of operation per year.

The operating advantages and economies possible with diesel locomotives are obtainable by precision maintenance and repair. A diesel-electric locomotive is composed of many elements requiring trained personnel for its proper upkeep and for realizing the higher availability and low operating cost inherent in this type of motive power. A diesel locomotive functions best when properly maintained. By observing the necessary precautions with regard to operation, following recommended maintenance procedures, and keeping the locomotive clean, the industrial user will achieve an economy of operation hitherto unattainable with reciprocating steam motive power.

Table I. Typical Steel Plant

Comparison of Operating Costs of Steam and Diesel-Electric Locomotives

	Dollars Per Hour	
	Present Steam	50-Ton Diesel
Fuel	$ 0.698	$ 0.330
Lubricants	0.045	0.033
Water	0.032	
Supplies	0.073	0.040
Repairs	1.272	0.350
Total	$ 2.120	$ 0.753
Hours per year	13,660	13,660
Annual operating expense	$28,959	$10,286
Annual operating savings by use of diesels		$18,673

Digest of paper 49-176, "Industrial Plants Prefer Diesel-Electric Switching Locomotives," recommended by the AIEE Land Transportation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Relaying on Sunbury Transmission Lines

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IN PLANNING the development of the transmission facilities needed for the output of the initial installation of two 75,000-kw units at the new Sunbury plant of the Pennsylvania Power and Light Company, provision of "spare" lines has been avoided by placing full dependence on the ability of fast protective and reclosing relaying to reduce line outages to short durations for all except the relatively rare faults that are inherently persistent. Because of this dependence upon modern relaying, the number of lines has been limited to those already existent in close proximity, which are simply being extended into Sunbury, plus three new ones that are required for load-carrying capacity regardless of relaying. (See Figure 1.)

Recognizing that the relatively rare occurrence on peak of faults that are inherently persistent will not justify spare lines, the functional requirements of the relaying for these lines are: to clear all inherently nonpersistent faults quickly enough to keep them from becoming persistent; and to reclose the terminal circuit breakers quickly enough to give reasonable assurance that the line will be back in service before some other line in its group is faulted. Experience with other lines indicates that these objectives can be met with fast protective relays and reclosure within two or three seconds. There is no stability problem.

Some of the special problems that had to be considered in the selection of relays were: the difficulty of reaching faults at the ends of tap lines because of the apparent increase in the impedances seen by the terminal relays; the desirability of avoiding overtripping for faults on the low-voltage feeders out of tapped step-down substations; and the necessity for opening low-voltage ties feeding back into the lines through tapped delta-connected step-down transformers, to avoid having sustained arcing grounds prevent successful reclosure.

For the phase protective relays, 3-zone impedance type *HZM*, having modified (offset) characteristics, were selected as best meeting all of the particular requirements. As usual, all three zones will trip through directional elements independently of carrier control, after their respective time delays. For carrier control, the third zone will be almost completely offset to make it largely directional and will control carrier starting; the second zone, covering the entire line, will trip instantaneously unless restrained by a carrier blocking signal. The directional starting of carrier allows sequential tripping of the two main terminal circuit breakers for faults on long taps, which might be within the reach of the carrier starting relays but not the tripping relays at one terminal.

For the ground relays, carrier-pilot protection is being provided by two sets of directional instantaneous units, one for tripping and one for carrier starting. This arrangement again allows sequential tripping, as carrier is not started for ground faults on the line. Independent back-up relays are being provided for the ground relays, but not for the phase relays. Interruption of feedback from low-voltage ties through tapped transformers is being accomplished by the use of very sensitive power directional relays.

Automatic reclosure of the main-line terminal circuit breakers will be made with 1-shot reclosing relays with timers to delay reclosure long enough to allow for sequential tripping of the terminal circuit breakers and for interruption of low-voltage feedback. Total restoration times for the first shot will vary between 30 and 100 cycles from the inception of the fault, which is considered quite adequate. Low-voltage ties will then reclose automatically if line reclosure is successful.

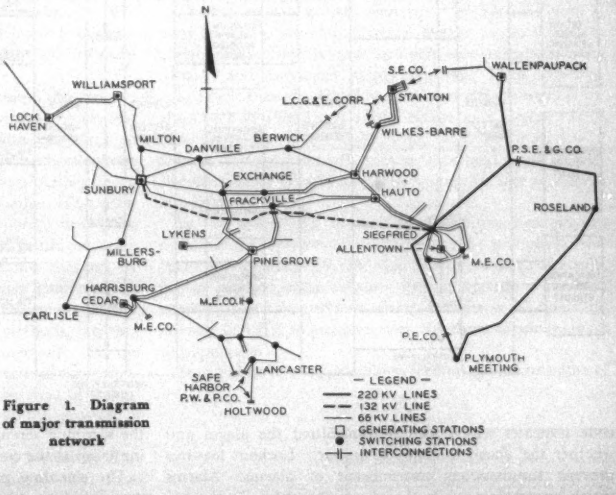

Figure 1. Diagram of major transmission network

Digest of paper 49-153, "Relaying of Transmission Lines From the New Sunbury Generating Station," recommended by the AIEE Relay Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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B-1 Alarm and Control System

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THE *B-1* alarm and control system provides means of supervising and controlling equipment in locations which are remote from a designated control point. The controlled stations may be spaced at intervals on a line extending in one direction or divided between lines extending in two, three, or four directions. Ten stations may be controlled from one control point.

This system was designed for controlling equipment at main stations along a coaxial cable route. Alarm conditions originating in these main stations or received by them are transmitted to the control station by a pulse code. The code indicates which station transmitted the alarm and whether the alarm is major or minor. Lockout features prevent simultaneous transmission of alarms. Alarms which accumulate while the alarm channel is in use are transmitted in sequence to the control station when the alarm circuit is free. At the control station, separate lights are assigned for the major and minor alarms from each controlled station. When either type of alarm is received, an audible alarm is sounded. By operating a key, the audible alarm may be silenced and the alarm condition can be transferred to a set of storage lamps leaving the first-mentioned lamps free to receive new alarms.

Orders are transmitted from the control station with three digits on a 10-unit dial. The first digit selects the station to be affected by conditioning the order circuit in that station to accept the next two digits. The order circuits in all other stations of the group are disabled. The second and third digits can transmit any required number of orders from one to 100. Among the functions performed by these orders are cable switching, battery charging, resetting pilot level relays, and starting the indication circuit. Each time that an order is addressed to a station, the alarm lamps for that station will be extinguished but if the alarm condition still exists, a new alarm will be transmitted to the control station.

The indication circuit is arranged to scan 168 contacts at an unattended station and relay the presence of ground on any contact to the control station where a lamp bank records the information. The pulses generated at the controlled station to step the scanning unit are also transmitted over a channel to the control station where they operate a counting chain which prepares the operating paths for the indicating lamps in rotation. Each time the scanning circuit encounters a ground, the corresponding lamp at the control station is activated.

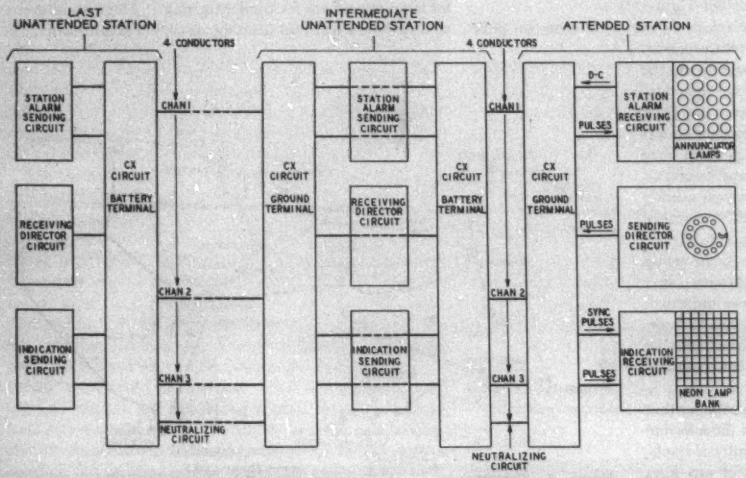

Figure 1. Block diagram of signaling system

The signaling paths between stations are obtained by compositing a 4-wire telephone order wire circuit. This provides four d-c channels. The first channel is used for the transmission of alarms. The second transmits orders from the control station and transmits the scanning pulses to the control station. The third channel transmits indication signals to the control station. The fourth channel is used as a neutralizing path common to the other three channels for neutralizing the effect of ground potential or other longitudinal interference in the operating circuits.

Digest of paper 49-155, "B-1 Alarm and Control System for Remote Control of Coaxial Cable Stations," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Expanding the Pacific Coast Telephone Network

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Since 1941, the population of the area served by The Pacific Telephone and Telegraph Company and local connecting utilities has grown by 50 per cent. To meet the concomitant increase in demand for telephone facilities, these companies are installing new transmission and terminal equipment. The sites and types of carrier used at each installation are described.

THE EVENTS of 1849 brought to the Pacific Coast of United States an enormous insurge of population, new industries, and a vast stimulus to message communications. A century later history is repeating, but on a much larger scale. During the past decade, the Pacific Coast has experienced an unprecedented influx of population, far greater in numbers than that of a century ago. With this migration came revolutionary changes in industry and a soaring demand for expansion of electrical communication facilities.

The telephone was introduced in San Francisco in 1877 with 18 subscribers. The following year several toll telephone lines began to serve the gold mining fields of California.

A major turning point in telephonic communication was reached by 1915 when transcontinental wire telephony was inaugurated after construction of a line with four wires via Reno and Salt Lake City. The same year radiotelephone signals were successfully transmitted from Arlington to Paris, Panama, Mare Island, and Honolulu. The techniques for world-wide extension of telephony were thus demonstrated. Henceforth the emphasis would be upon multiplexing, and the ensuing decades are marked by successive advances in methods to permit commercially practical development of great numbers of circuits at ever lessening cost in comparison with older methods, together with the switching devices for interconnection. To the Pacific coastal area, these developments were of commanding importance, owing to its isolation by barriers of mountains and deserts to the eastward, and by the greatest of oceans on the westward.

Since 1914 the population of the area served by The Pacific Telephone and Telegraph Company and local connecting companies has grown from five million to 15 million with attendant industrial development (see Figure 1). To grow from five million to ten million required 25 years, but the great influx of people in the years during and since World War II has produced another five million, a 50 per cent increase in the ten years since 1939.

On the same chart, are shown the number of telephones (Pacific Company) and miles of toll circuits. Telephones grew from just over one-half million in 1914 to 3.7 millions in 1948. The effects of the depression and of World War II restrictions are evident in the otherwise steady advance. In addition, there are within the territory 636,000 connecting company telephones and 63,000 customer-owned "farmer line" telephones. Since 1914, when wire facilities permitted setting up a few telephone circuits from San Francisco to points as distant as Los Angeles, Portland, and Reno, but not to points further east, the telephone network has grown, in two major waves of development, until there are now hundreds of circuits on the major coast-wide and transcontinental routes, besides radiotelephone overseas circuits spanning the Pacific (Figure 2).

The first wave of growth, shown by the chart of Figure 1, prior to 1930, was characterized by the use of voice-frequency cable circuits and by open wire telephone lines with 1- and 3-channel carrier systems. These developments have been described in a series of papers, notably by Hitchcock in 1923,[1] and 1926,[2] Nance and Jacobs, 1926,[3] Chamberlin in 1928,[4] Calderwood and Smith in 1932.[5] During this period, toll circuits increased from 70,000 circuit miles to 240,000, far outstripping the rate of growth of population.

In the late 1930's, the revival of business brought the numbers of telephones and toll messages to new peaks, and then the beginning of World War II set up a demand resulting in another sharp advance during and since the war years to about 2.2 millions of circuit miles or 30 times the amount in 1915, to compare with the three to one increase in population.

It would have been possible to resume the construction of

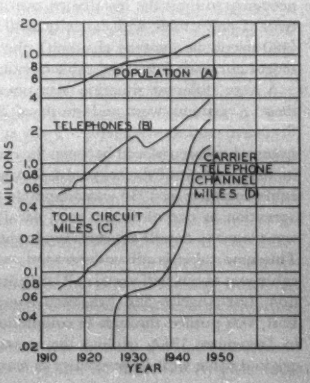

Figure 1. Growth of population and telephone network in area served by The Pacific Telephone and Telegraph Company and local connecting companies

Essential substance of a conference paper presented at the AIEE Pacific General Meeting, San Francisco, Calif., August 23–26, 1949.

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the voice-frequency cable network which had been halted in 1930. Most fortunately, however, the activity of Bell System research and development engineers during the depression years had made ready new carrier systems, providing circuits of greater transmission capabilities and making such effective use of existing open wire lines and cables, both aerial and subsurface, that the requirements for copper, lead, poles, and right-of-way were greatly lessened, with consequent reduction in costs. These new systems are the *J* carrier,[6] providing 12 2-way telephone channels on one pair of open wire, and the *K* carrier,[7] providing 12 channels on two pairs of standard 19-gauge voice-frequency toll cable, one nonloaded pair being used for each direction of transmission. Applicable to long-haul routes requiring hundreds or thousands of circuits, coaxial cable structures in the *L* carrier system[8] and microwave radio techniques in the *TD* radio relay systems[9,10] further enlarge the range of choice of instrumentalities.

DESCRIPTION OF PACIFIC COAST APPLICATIONS

1. K Cable Carrier System. The urge to make stormproof the major Portland–East route through the Columbia River Gorge and the major Oregon–California route in the Sacramento River Canyon between Redding and Weed, and the need for more circuits in these sections led to the first use of *K* carrier on the Pacific Coast. New cables arranged for *K* carrier were placed in service from Portland to Wyeth (50 miles) and between Redding and Weed (71 miles) in 1941, greatly reducing the hazards of interruption by sleet on the open wire lines.

The several transcontinental routes (all on open wire in the West except close to their terminals) required relief. Studies of routes and systems led to selection of the Omaha–Salt Lake–Sacramento path via the Donner Pass through the Sierra Nevadas, for extension of *K* carrier systems westward from Omaha. Between Omaha and Sacramento, there were almost no existing toll cables that might serve as part of an all-cable line, hence it was necessary to place twin cables on a new route to accommodate *K* carrier. Over long stretches in Nevada, provision of access roads and power supply to the repeater stations proved to be major problems. Because of wartime shortages, it was necessary to limit the installation over most of the route to twin 61-pair cables, with capacity of 40 long-haul *K* systems (480 telephone message channels) plus a small number of short-haul voice-frequency cable circuits.

A very different situation was presented in extending these *K* systems west and south of Sacramento to San Francisco and Los Angeles. Twin cables suitable for *K* systems had been placed between Sacramento and Stockton in 1941. Most of the original Los Angeles–San Francisco cable complete in 1930 was adaptable for conversion to *K* operation in one direction; so a paralleling 61-pair cable was placed to handle transmission in the opposite direction. This new cable is all underground, whereas the original cable was about half aerial. The entire *K* system installation, Los Angeles–San Francisco–Sacramento and to the East, was pushed through to completion for initial service in December 1942, tripling the message capacity of the original cable with large savings in scarce materials, labor, and cost, compared with earlier methods. (See Figure 2).

K carrier development on the Pacific Coast is rounded out by applications to cables connecting Portland to Seattle, Salem, and The Dalles, Los Angeles to Whitewater and San Diego, and finally Oakland to Sacramento via the direct route—a total of 1,600 route miles and 740,000-circuit miles.

2. J Open Wire Carrier Systems. Beginning with Whitewater to Oklahoma City in 1939, *J* systems, each providing an additional 12 circuits over a pair of wires already carrying four circuits, have been placed in service on almost all major open wire routes in the West. The 12 systems placed in service between Klamath Falls and The Dalles along the Columbia River helped to defer the Sacramento–Portland cable project until after the war.

Early in 1942 the need for additional facilities in connection with the war effort dictated provision of a major telephone line from southern California to the Pacific Northwest via a route east of the Sierra Nevada and Cascade Mountains. Authorization was given in April 1942 for all-out effort in completing new open wire pole lines from Las Vegas, Nev., via Reno to Klamath Falls, Yakima, and The Dalles, and a 67-mile tie line in southern California, all suitable for *J* systems. Including some branch lines en route, this totaled 892 miles of new pole line. New wire was added on 425 miles of existing pole lines, such as Klamath Falls to The Dalles.

By emergency methods of engineering and assembly of materials, and with help of construction crews and equipment borrowed from several midwestern and eastern telephone companies, the first relief was provided via the new lines within five months of authorization—a record-breaking performance. Such a project would normally involve years in planning and execution.

The line was designed to carry eight pairs of wires capable of handling 128 message telephone circuits—16 circuits on each pair by means of *C* and *J* carriers. It continues to operate at nearly full capacity.

Most of the open wire lines shown in Figure 2 including three transcontinental open wire lines are *J* carrier equipped. There are 4,200 route miles and 202,000 toll circuit miles on a *J* carrier basis.

3. L Carrier System Applications. When additional transcontinental circuits became necessary, because of exhaustion of facilities in the *K* cable from Omaha to Sacramento, as previously mentioned, a coaxial cable to Los Angeles via Dallas and Phoenix was undertaken. The Dallas–Los Angeles section, comprising about 1,600 miles with eight coaxials, was placed in service in November 1947. One pair of coaxials now has a full complement of *L-1* equipment, comprising 600 voice-telephone channels with a second pair equipped and operating as a fall-back for protection of service.

By 1945 every channel that could be crowded on to the open wire lines joining Salt Lake, Reno, and Sacramento to Oregon and Washington was in use. Prospective growth clearly indicated a major cable project. Studies for type of structure led to the choice of coaxial cable from Sacra-

mento to Portland, via Redding and Medford, with quadded pairs included in the cables for short haul circuits.

A 6-coaxial plus 54-quad cable was placed from Sacramento to Marysville in 1946. The remainder of the cable from Marysville to Portland, placed in service in June 1948, was provided with eight coaxials. From Sacramento to Portland the route is 584 miles with dropping points for coaxial circuits at Redding, Medford, and Eugene. Four coaxials are currently in service, two for message traffic and special services and two for protection of service.

Studies in 1946 of procedure for adding circuit capacity between central and southern California led to selection of coaxial construction from Oakland to Los Angeles via Salinas and Santa Barbara, having in view the fully developed *K* and voice-frequency cable system in the Stockton–Bakersfield route. To meet urgent short-haul requirements for quadded pairs which can be included within the same sheath as the coaxials, the Oakland–San Jose, Santa Barbara–Ventura, and Van Nuys–Los Angeles sections have been placed in advance of the rest of the route.

The major open wire toll route eastward from Seattle, traversing the rugged Cascade Mountains, has presented a severe maintenance problem because of extremely severe winter weather. Construction of a 4-coaxial cable is now in progress on a 130-mile route from Seattle to Yakima. The coaxial cable will greatly increase the capacity and security for this line from Seattle to the important existing and prospective developments of the Columbia River Basin, and the transcontinental routes via Spokane and Boise.

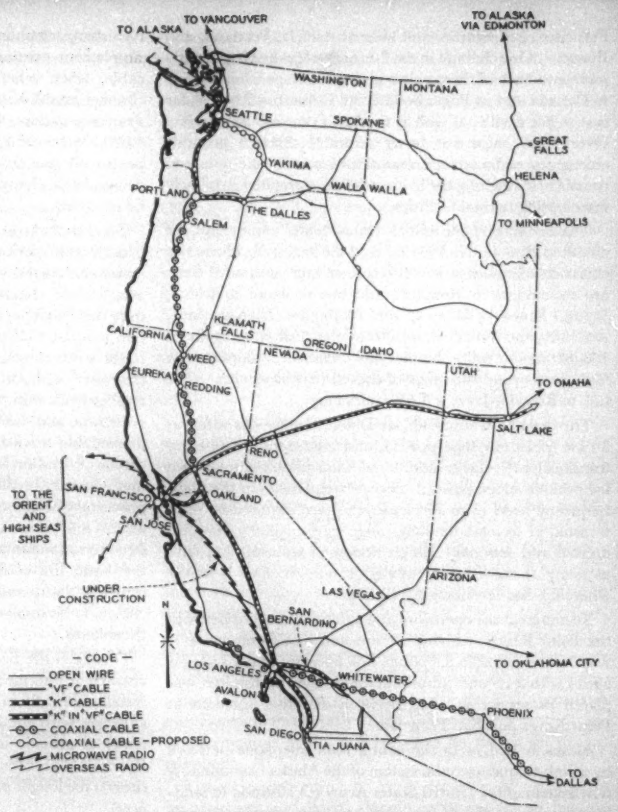

Figure 2. Major long-distance routes of The Pacific Telephone and Telegraph Company

The great number of circuits concentrated within a single-coaxial sheath make necessary extraordinary precautions. On coaxial cable routes, this has led to: laying twin cables at important submarine crossings; structural reinforcement of duct structures at points of exposure to washouts; placing buried cable deeper underground than temperature control would dictate, sometimes six feet or more; frequent warning signs and cable location markers; elaborate alarm systems to detect failure of gas pressure in the cables and to warn of failures at unattended repeater points.

4. Radio Applications. The use of radio as a servant of the Pacific Coast commercial telephone network began with the "historic first" commercial radiotelephone service between Catalina Island and Los Angeles in 1920. This was superseded by submarine cable in 1923,[1] and an 8-channel microwave system now serves the Catalina–Los Angeles path, supplementing the cables. A 16-channel microwave relay system served nearly a year during 1947-1948 for traffic relief on a major open wire land route until cable could be completed (Marysville to Redding, 115 miles with one relay station). The same 16-channel system now fulfills a similar task, working from Oakland to Santa Rosa via Mount Tamalpais. The *AN/TRC6* microwave radio system, using pulse-position molulation at 4,000 megacyles, is used in all three cases.[11] Developments in microwave relay equipment indicate that in the near future it will be a formidable competitor not only for handling television transmission but also for message traffic on routes requiring hundreds of long-haul circuits with limited short-haul needs.

Coastal harbor radio service between the land-line system and ships was instituted in the 1930's at Los Angeles, San

Francisco, and Seattle, and later at Astoria, Portland, and Eureka. One channel in the 2-megacycle range is currently serving at each of these points giving coverage from Mexico to Canada and in Puget Sound, the Columbia River as far east as Bonneville, as well as the San Francisco Bay region. Over 3,800 ships are being served.[13] Sixteen portable emergency radio sets are maintained at strategic points to permit bridging of gaps in event of catastrophe completely interrupting normal facilities.

The opening of the initial trans-Pacific radiotelephone circuit to Honolulu in 1931 marked the beginning of a major extension of coverage which has since increased until there are six circuits to Honolulu and one or more to China, Japan, Korea, Okinawa, the Philippine Islands, Java, Australia, and New Zealand, 20 circuits in all, totaling about 100,000 circuit miles, besides one channel for ships on the high seas beyond the range of coastal harbor service. The link to Batavia, Java, is 8,650 miles long.

The original transmitter, at Dixon, Calif., was rated at 80 kw (peak envelope power), and used double side-band transmission.[13] Later additional transmitters employ two kw peak envelope power. Several frequencies in the high-frequency band (3 to 30 megacycles) are required by each transmitter to meet the long-range transmission variations, diurnal and seasonal. Single side-band transmission, with as many as three voice circuits on one channel, is in use where far-end terminals are suitable.

To augment the open wire and cable connections between the Point Reyes receiving station and San Francisco a 1-way 3-channel radio telephone link operating at 161 megacycles with a 15-watt amplitude-modulated transmitter was placed in service in 1940 between directive antennas at Point Reyes and San Francisco.

Alaska is tied in to the commercial telephone network by a high-frequency radio system of the Alaska Communication System of the United States Army (in addition to land-line circuits via the Alcan highway) with several channels connecting Alaskan centers and the land-line system at Seattle.

In 1946 urban mobile radio service was begun at San Francisco serving railway yard locomotives as well as automobiles, trucks, and, later, ships. This service has extended until there are 13 channels in service serving more than 500 mobile stations in ten cities.[14] Highway mobile radio service now employing 13 land transmitters and about 60 land receivers serves some 250 vehicles. It was begun in 1947 on the Portland–Salem–Eugene route.

Single-channel radio links connecting Portland to Mt. Hood, Spectre Mountain, Nev., to Death Valley, San Diego to Mt. Woodson, Fresno to Joaquin Ridge, Newhall to Liebre Mountain, and Mt. Toro to Los Padres Dam are instances of point-to-point service in locations where wire line construction presented unusual difficulties and it was found practicable to utilize frequencies and equipment of the kind developed for the mobile services just described.

Early in 1948 an intensive investigation of the terrain between Los Angeles and San Francisco was begun, to determine the design of a microwave relay route for the earliest practicable transmission of television, and suitable for furnishing telephone message circuits in large numbers to supplement existing land-line routes, both open wire and cable, when relief is needed. A wartime experimental channel established by the United States Army from San Francisco to San Diego,[15] had shown that transmission with 4,000-megacycle equipment of the *AN/TRC6* type was practicable but that large variations in transmission due to tropospheric changes and earth surface reflections were to be expected.

Measurement of the variation of transmission loss over considerable periods of time was undertaken to explore seasonal changes, utilizing typical paths of varying lengths and surface characteristics northward from Los Angeles over the Tehachapi Mountains and via the west side of the San Joaquin Valley and Mt. Diablo to San Francisco. All paths were chosen to have at least "first Fresnel Zone" clearance without allowance for refraction. Besides the requirement that transmission be of sufficient signal-to-noise ratio and stability between repeater stations to provide dependable service, a host of considerations influence the choice of sites, such as access roads for construction and for maintenance, availability of commercial power supply, provision of auxiliary communication for conveying failure-alarms and automatic controls. With the bold and varied structure of mountain and plain encountered in this region, the basic line-of-sight criterion can be met over many routes without resort to towers, leaving great latitude of choice, to be resolved by obtaining the best balance among these items.

For the entire route between Los Angeles and San Francisco eight intermediate repeaters will be used in the initial installation. Several of the buildings are now under construction with the objective of having the initial channels ready to provide television service in the spring of 1950. Provision has been made for additional repeater station sites on the longer paths as future requirements may develop need.

The Mt. Diablo repeater station, on the west shoulder about one-half mile from the summit, is within the State Park. The building and location have been specified in co-operation with the State Park Commission to be in full harmony with the recreational purposes of the park.

TOLL DIALING

A discussion of "Expanding the Pacific Coast Telephone Network" would not be complete without mentioning the steps toward mechanization for the handling of the enormous volume of toll traffic carried by such a network. This is proceeding in two categories, namely, operator toll dialing and customer toll dialing. The former is being developed on a nation-wide basis. The latter requires one of several forms of automatic machine recording of toll tickets, or the employment of a message unit rate schedule, with automatic metering of each customer's message unit usage, and at present is being applied only where heavy volumes of short-haul traffic are involved. Both have the objective of greatly speeding and improving the accuracy of service and increasing efficiency in the employment of facilities and personnel. They are directly related to the

increasing use of dial arrangements in local offices. At the end of 1948, 81 per cent of the telephones served by the Pacific Company were on a dial basis.

1. Operator Toll Dialing. Operator toll dialing is the system by which an outward toll operator at the originating point reaches the called telephone in a distant city by the use of dial equipment without the help of any other operator. The calling customer at the originating point reaches the long distance operator in the usual manner, who then completes the call by dialing the necessary codes and the called number. The operator receives distinctive signals to tell her when the called customer answers or that his line is busy or that all toll circuits are busy. Provision is also made for her to reach information or other operators if their assistance is necessary in completion of the call.

Scores of communities have for years been furnished local telephone service through local dial offices. Gradually the range of the dial mechanism has been extended, first to near-by towns and then to the establishment of short-haul toll networks. Today such short-haul toll networks are used extensively. On the Pacific Coast they center around the metropolitan areas of Seattle, Portland, San Francisco, Los Angeles, and San Diego, which have a high community of interest with near-by cities, and certain inland cities which have sizeable communication requirements not only between themselves and near-by communities but also to one or more of the adjacent metropolitan areas named.

The inherent design of the foregoing networks has restricted their application to the requirements of short-haul toll traffic, that is, in general, to direct circuit traffic or to 1-switch traffic, involving in either case circuits not exceeding one or two hundred miles in length. This is due in part to design economies being pointed to the needs of a particular field of usage and in part to the fact that technical arrangements necessary to extend dial switching to long-haul multiswitch traffic have only recently become available.

The following presents chronologically a history of toll dialing expansion on the Pacific Coast:

1925—Trial installation of a short-haul operator toll dial switching system in Seattle using panel-type equipment—called panel tandem system.

1926—Step-by-step tandem system placed in service in Los Angeles, handling calls between metropolitan Los Angeles and 30 outlying exchanges;[17] also similar system at San Diego.

1930—Anaheim (Orange County) step-by-step tandem system instituted.

1942—San Francisco and Oakland crossbar tandem equipment installed. Initially to handle customer-dialed interzone traffic within the San Francisco–East Bay exchange, and later expanded to handle operator-dialed toll traffic between the metropolitan area and some 31 outlying toll centers and tributaries.

1945–1948—Sacramento step-by-step intertoll system was installed in 1945 followed by similar systems at Portland and other points; also crossbar tandem systems at Seattle and Los Angeles.

Development work had been in progress for some years before World War II on a toll switching system of the crossbar type which would meet the requirements of long-haul toll dialing and which, with suitable changes in methods and facilities, would permit the interconnection and expansion of the isolated networks in various parts of the country into a nation-wide system. A trial installation of this new toll switching system, commonly referred to as the Number *4* toll crossbar system, was made at Philadelphia in the latter part of 1943 and is described in a paper by Abraham, Busch, and Shipley.[18]

Number *4* toll crossbar installations similar to that at Philadelphia were completed in 1948 at New York and Chicago, and will be completed this year at Cleveland, Boston, and Oakland, the latter being the first such installation on the Pacific Coast. They will be followed in later years by many similar installations including the more important Pacific Coast centers, Los Angeles, Fresno, Sacramento, Portland, and Seattle. The timing of a given installation is determined by economic considerations which must take into account factors local to the center under study as well as its relationship to the dialing network as a whole.

Following cutover this fall, some 1,100 dial intertoll trunks will be connected with the Oakland Number *4* toll crossbar equipment. These intertoll trunks will serve 40 toll centers of which 12 are outside the Pacific Coast states, including Chicago and New York, and 28 are Pacific Company points. Some 925 ringdown intertoll trunks will remain connected to the manually operated toll switchboards at Oakland. The ringdown facilities will be transferred to dial operation as rapidly as feasible after dialing arrangements become available at the distant toll centers.

With some modification to be applied later, the toll crossbar switching equipments, of which the installation at Oakland is typical, will select one of several alternate routes, automatically passing to successive choices if all circuits in the first route tested prove busy and operating the switches at intermediate points, will complete the call to the distant telephone.

The new service will be more accurate, less subject to interruptions and faster, thereby reducing circuit holding time, and flexible in application so that cities can be added to the dialing network as conditions warrant. Besides the improvement in service, over-all economies may result as the dialing network develops.

2. Customer Toll Dialing. Customer toll dialing requires the application of one of several methods for the automatic machine recording of toll ticket information so that a customer can complete his own short-haul toll calls without the services of an operator. The particular arrangement employed depends on the type of local dial equipment used at a given center.

Where the local equipment is of the step-by-step type, equipment is employed which automatically prepares an individual printed ticket showing the information needed for charging the call. This arrangement is commonly referred to as Automatic Ticketing Equipment or *AT*. The first installation of this equipment was made at Culver City (near Los Angeles) in 1944.[19] Similar installations have been made at several points in northern and southern California, and other installations are scheduled.

Where the local dial equipment is of the crossbar type the call charge information necessary to the proper billing

of the call is recorded by a system known as Automatic Message Accounting or *AMA*. In this system the equipment at the local central office distinguishes whether the subscriber is making a local flat-rate call, a message rate call, toll or local, or a toll call to some point to which he is permitted to dial his own calls and for which a detailed bill is required.

All information is recorded as coded numerals punched on a 3-inch-wide paper tape (message units, toll or local, where message rates apply, or in the case of a detail-billed toll call, the month, day, and exact time at which conversation begins and ends). Each of these entries is made on the tape in a fraction of a second and details of a number of calls may be recorded on the same tape as they occur. These tapes are collected daily from the local offices using this system and taken to an accounting center serving the entire area. There the tapes are "read" by special accounting machinery and the call information automatically sorted out for billing.

A trial installation of *AMA* equipment was made at Media, Pa., (near Philadelphia) in 1948. Other installations now are in use and more are being planned, including a number of offices on the Pacific Coast.

Each proposed application of customer dialing involves an economic study in which savings in traffic and accounting expense are balanced against the charges for the necessary automatic arrangements, the latter being sizeable. Ordinarily, the application proves in only where large volumes of short-haul toll traffic are involved.

CONCLUSIONS

Since 1915, when transcontinental telephone service was first established, the Pacific Coast area has increased threefold in population, sevenfold in telephones, and thirtyfold in telephone toll circuit mileage. Growth has been so rapid that facilities have usually been fully utilized earlier than was indicated at the time of construction. The newer methods of providing channels are characterized by ever-advancing complexity of terminal arrangements and decreasing demands for intermediate line structures and materials until in the radio relay links the only requirement between stations is a reasonably stable line-of-sight pathway. Flexibility and dependability have been enormously increased and new areas served by a multiplicity of routes in contrast with the single-route layout of 1915.

Along with the increase in numbers of communication paths between communities has come toll dialing, a machine method of interconnecting these paths. This is a major contribution to giving faster, more accurate, and more dependable long distance service.

The picture here presented is limited to some of the larger or more novel commercial telephone developments of one organization. A complete picture of the Pacific Coast communications growth would require consideration of the activities of some 265 connecting telephone companies, telegraph companies, both wire and radio, railroad, power, and petroleum companies, and local, state, and national governmental organizations.

Besides meeting the phenomenal growth of the past decade, the facilities now in place and under construction on the Pacific Coast have capacity for presently foreseen needs, including intercity television. Viewing the prospects of this coastal region there is every reason to believe that in the next decade, as in those past, demand will continue to grow and that facilities now ready or in process of construction will be fully utilized, expanded, and extended.

The economic effect of the new techniques for meeting growth and providing new services has been to reduce the cost of a unit length of circuit on the more heavily developed routes while providing facilities of larger capabilities, adaptable for new services.

There is no sign of an end to development. Methods of doubling the capacity of coaxials and greatly expanding the capacity of cables on short-haul routes by new carrier techniques are but two illustrations of new tools in prospect to add to the wide field of choice in building a network to provide the best service at the least cost, wherever it is found to be needed.

To harness these developments to the service of a rapidly growing region has required a large amount of capital. This process must continue if the communication art is to keep pace with the needs of its customers and only by such technological strides as those described can these needs be met economically.

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A Thermal Converter for Telemetering

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A THERMAL CONVERTER, used as a primary element in the telemetering or totalizing of large power loads, is a measuring instrument which generates a direct voltage accurately proportional to the power of the a-c circuit measured. The output voltages of two or more converters may be connected in series and the algebraic sum of the loads so totalized may be recorded or indicated, remotely if desired, by a potentiometer. In principle, the thermal converter comprises an a-c circuit such that the difference in power generated in two heaters is proportional to the measured load; and the temperature difference thus produced is measured by thermocouples. In addition to power the thermal converter may be adapted to measure reactive power, power factor, current, or voltage.

A new type of thermal converter has been developed to obtain the relatively higher speed and efficiency available through direct contact between heaters and thermocouples without introducing into the thermocouple circuit alternating voltages which subsequently must be eliminated. This is accomplished by isolating each heater, except for its one point of contact with a thermocouple junction.

The principle employed is illustrated in Figure 1, which is simplified to show only one thermocouple and two heaters of equal resistance, R. Each heater is supplied from isolated secondary windings on a potential transformer and on a current transformer which are connected in series; the polarity of the connection between these windings is opposite in the two cases. Due to the effect of line voltage alone a current component $e/2R$ circulates through each heater; due to line current alone a current component $i/2$ flows through each heater. These current components add, in one heater, to give current $(e/2R+i/2)$, and in the other heater subtract to give current $(e/2R-i/2)$. If p_1 and p_2 represent instantaneous power in each heater,

$$p_1=(e/2R+i/2)^2R=(e/2R)^2R+ei/2+(i/2)^2R \quad (1)$$

$$p_2=(e/2R-i/2)^2R=(e/2R)^2R-ei/2+(i/2)^2R \quad (2)$$

$$\Delta p=p_1-p_2=ei \quad (3)$$

The average difference of power to the two heaters, where E and I are rms values of voltage and current and θ is the phase angle between them, is

$$\Delta P=EI\cos\theta \quad (4)$$

The output voltage of a thermocouple measuring the temperature difference between these heaters is thus a function of the power to the load which is being measured.

In actual construction, each thermocouple of Figure 1 consists of a pair of opposing thermocouples, each with a "hot junction" at a heater and the "cold junctions" all at a common reference temperature. Six such thermocouple pairs are employed in a single-element converter and the potential and current transformers each, accordingly, have 12 isolated secondary windings to supply the 12 heaters.

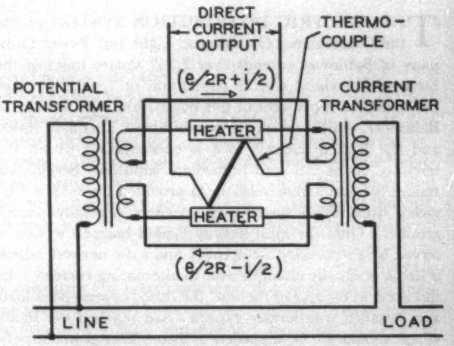

Figure 1. Basic thermal converter circuit

A linear relation between the power input to each heater and the voltage from its associated thermocouple is obtained through the use of two metals of opposite temperature coefficient of thermal conductivity in the construction of the heaters and thermocouples. Proper proportioning of the heat flow between the two materials results in a temperature rise versus power input relation which balances the tendency of the thermoelectric power to vary as a function of the temperature.

If the assumptions of equal resistances and of equal "efficiency" of each heater in raising the couple junction temperature, made in deriving equation 4, are not accurately met, equation 4 may be shown to include error terms proportional to E^2 and to I^2. In order to permit accurate adjustment under all conditions additional thermocouples, heated proportionally to E^2 or I^2, are employed and an adjustable portion of the voltages so generated introduced in series with the main output circuit.

Continuous adjustment of output ratio, from zero to maximum, is provided by a potential divider across one pair of main output couples and by a selector link which permits removal of one or more pairs of couples from the output circuit.

In output ratio, speed of response, and freedom from a-c component, this new converter represents a compromise between the characteristics of existing converter types. Early tests indicate that its accuracy under all conditions equals or exceeds that of existing converters. The design is, in general, adaptable to the measurement of any type of circuit of commercial voltage, current, and frequency rating.

Digest of paper 49-459, "A Thermal Converter for Telemetering and Totalizing," recommended by the AIEE Joint Subcommittee on Telemetering and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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"Multiplex" Scheme in Urban Distribution

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THE ELECTRIC DISTRIBUTION SYSTEM of the the Consolidated Gas Electric Light and Power Company of Baltimore extends over 2,269 square miles in the State of Maryland with a population of 1,400,000. Approximately 70 per cent of this population is in the city of Baltimore, which covers an area of about 73 square miles, and the bulk of electric load is concentrated within the territory of the city and immediate suburbs. Service for residential and commercial use is provided there by a 4-kv radial distribution system, with feeders generally underground. Only the most heavily loaded business section is served by a secondary a-c network and a d-c network which is being gradually changed over to alternating current. In this area, at the end of the war, the ratio between peak load and installed transformer capacity had reached the limits which should not be exceeded to assure firm power supply at all locations. Temporary provisions, like the use of portable fans during emergencies, were put into effect, but the need for new facilities became urgent and a decision had to be made as to the best method for expansion.

As a result of previous studies, it was concluded that the 4-kv radial distribution offered the best method for expansion and that new substations should be installed in the peripheral areas of the city, rather than add new capacity at present sites.

A survey was made of modern trends in the design of similar substations and of the equipment available, with particular attention to factory-assembled metal-clad switchgear. Proposals were obtained from manufacturers for various schemes and layouts and, following a careful comparison of costs and operating features, it was decided to adopt for the proposed substations a new scheme, designated as "multiplex," which was suggested by the engineering department of the company.

This scheme, using the "building block" principle, was examined for all basic requirements for urban service, with a minimum of equipment. As shown by Figure 1, the building block "unit," of which one is circled by broken line, consists of a transformer and an assembly of switchgear elements comprising two feeder circuit breakers (*A*) with their respective potheads, and one tie circuit breaker (*B*). All "units" are identical and are connected as a ring, with the tie circuit breakers normally open, so that each pair of feeders is supplied by its own transformer independently from other "units."

To assure continuity of service in the event of failure of a transformer or of its high voltage supply, adequate relaying is provided to cause the following sequence of operations: the transformer (for instance, *I* on Figure 1) is de-energized; its two feeder circuit breakers (*2* and *3*) open; immediately thereafter, the two contiguous tie circuit breakers (*1* and *4*) close. The feeders which were supplied by transformer *I*, will thus be automatically transferred to the adjacent transformers *II* and *III*, with only a momentary outage.

In relation to the load densities expected to exist within the next ten years in the territory served by the new substations, an average peak load capacity of 1,500 kva was considered adequate for the 4-kv feeders. This, in turn, determined the ratings of transformers, switchgear, and subtransmission lines. The transformers must be capable of carrying three feeders and the standard rating of 3,750 kva has been selected. Indoor metal-clad switchgear, with 600-ampere air circuit breakers of 100,000 kva interrupting capacity, is used at all city substations.

Each distribution area is supplied by a group of five underground high-voltage cables either 13-kv or 33-kv, with capability of 30,000 kva and 60,000 kva respectively. Generally, two or three substations, with various capacity allocations, are arranged on each group of high-voltage cables. The total capacity could as well be installed at a single substation, and this requisite of flexibility constitutes one of the desirable features of the "multiplex" scheme. The actual load growth in any area may differ from the assumptions made at the time a new supply is initiated, and a change in the number of substations originally planned may become economical. Seven substations of this type, are being installed in the Baltimore city area.

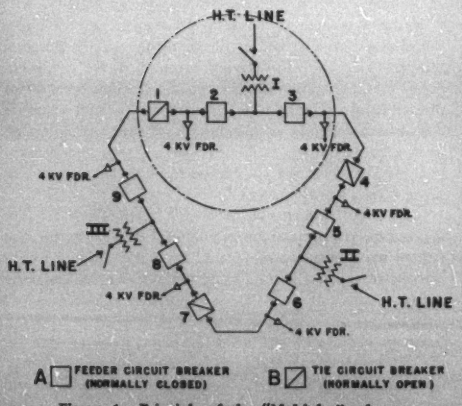

Figure 1. Principle of the "Multiplex" scheme

Identical "units," of which one is circled by broken line, are connected as a ring, with tie circuit breakers B normally open

Digest of paper 49-124, "Application of the 'Multiplex' Scheme at Urban Distribution Substations in Baltimore," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Not scheduled for publication in AIEE *Transactions*.

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Industrial Electronic Problems for Engineering Education

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A teacher can make his lectures immeasurably more valuable to his students if he will but take the time necessary to prepare carefully a number of problems illustrating the use of the material presented in the lectures. In addition, at the same time he should insist that the students, in turn, take the time necessary to work these problems out.

EVERY conscientious teacher considers it his primary duty to prepare his students as effectively as it is possible within the time limit provided for his lectures for the moment when they face the problems encountered in their profession. The opinion of different teachers may vary on the methods of best reaching this goal, but there hardly can be any disagreement on the goal itself. Fundamentally, the differences in opinion of how to reach it can best be stated by simply presenting the two extreme views pertaining to this matter: Is it better to spend the available time in skipping over the whole field and giving the student a smattering of everything in it, or is it wiser to concentrate on a few fundamentals of the field and to try to give the students as thorough an understanding of them as possible? The nature of the problems selected by a teacher for home and classroom work will greatly depend upon his view in this matter.

The old proverb, "Easy come, easy go," expressed the thought that nothing really becomes one's property, unless it has been acquired the hard way, that is, by hard work. The proverb is of course usually quoted with reference to material possessions, but it applies equally well to abstract things such as knowledge. Unfortunately, altogether too many students feel that attendance at the lectures is sufficient to acquire knowledge on the subject. Of course, nothing could be further from the truth. Only by the process of diligently working out the problems given in the classroom or for homework, will a student succeed in making the material his mental property. As soon as the truth of this is recognized by both the teacher and students, the selection of proper problems to illustrate the subject of the lecture assumes a much greater importance than is usually accorded it.

Naturally, a teacher will try to work out problems which, at least in his own opinion, will come as close as possible to the problems encountered in practice. Unfortunately, there are many and good reasons why such an attempt is not always successful. First, a teacher is sometimes correct in not even wanting his problem to be of the practical kind; quite often an artificially created problem, not liable to be met in actual practice, serves extremely well in driving home a given point. (A little further in this article a problem of this kind is presented.) Second, the instructor may not have had industrial experience, and for this reason might find it difficult, if not impossible, to think up problems such as enountered in practice. Third, the task of correcting the homework may, to a certain degree, limit the teacher in the choice of problems. The last statement may require a little elucidation. In actual practice an industrial electronic engineer may be faced with the task of designing a photoelectric relay which will operate from the light of a 60-watt Mazda lamp six feet away. Stated in this way, the problem is capable of an almost infinite variety of solutions. The engineer's superior certainly will not tell him what type of circuit, type of tube, or relay he should use, because to make that decision is exactly why the engineer was hired. If a teacher would present problems permitting such latitude in the solution, he would have a number of solutions, each of which he would have to check very carefully. There can hardly be a doubt that such a procedure would give the student an amount of self-reliance and confidence in his judgment not equalled by any other method of approach. But it is also easily seen that such a method is entirely out of the question with a class consisting of more than a handful of students. Even with only half a

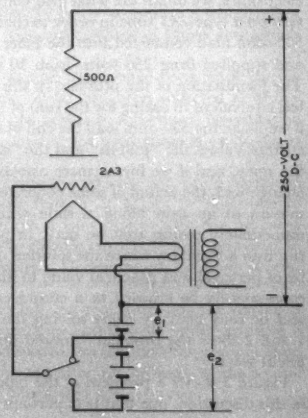

Figure 1. Problem

In the circuit shown, a type-2A3 tube is operated from a 250-volt d-c supply with a 500-ohm resistor as plate load

What two values e_1 and e_2 of grid voltage are necessary to produce plate currents of 5 milliamperes and of 50 milliamperes?

Essentially full text of a conference paper, "Industrial Electronic Problems for Engineering Education," presented at a Session on Problems and Thesis Subjects From Industry held during the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949.

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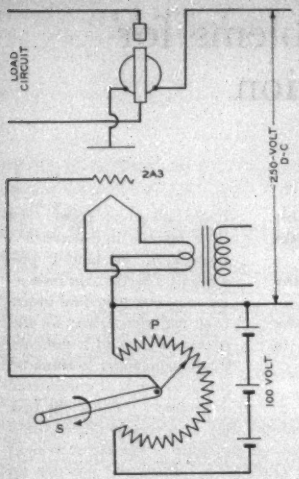


Figure 2. Problem

A relay with a 500-ohm coil is operated in the plate circuit of a type-2A3 tube; the d-c supply is 250 volts. The relay pulls in with 50-milliampere coil current and drops out with 5 milliamperes. Operation of the relay is to be made a function of the position of a shaft S, to which is connected the movable arm of potentiometer P, carrying a linear winding for 270 degrees of its circumference

With 100 volts applied to the potentiometer, at what angular positions of the arm will the relay pull in and drop out?

dozen students, the correction of the problems, if they were given in the manner just described, would make very severe demands on the time of the teacher. With a reasonably large class he has no other choice, much as he may regret it, than to specify the type of circuit, the tube to use, and so on, so that the correction of the problems practically comes down to checking the figures given in the answer.

Another factor which should not be overlooked in the preparation of problems, for industrial electronics or otherwise, is the simple psychological fact that it is easier to arouse interest in the problem of finding the sum of three apples and four apples, than in finding the sum of the two figures, 3 and 4. The failure to make use of this fact is a fault found perhaps most often in books on mathematics, because mathematicians appear to consider it a prostitution of their science if it is applied to anything practical. In industrial electronics, we might ask what grid voltage would be necessary on a type-*2A3* tube in order to change the current in a 500-ohm load connected into the plate circuit of the tube, and supplied from 250 volts, from 10 to 60 milliamperes. The formulation of the problem in this manner is more or less equivalent to asking for the sum of 3 and 4. However, if we make the 500-ohm load the coil of a relay, and the two current values the "pull-in" and the "drop-out" values for the relay, and if we furthermore associate the grid voltage change with the action of some concrete device, such as the motion of an arm along a slide wire, the student will immediately realize that he may, in practice, very easily run into a situation where the solution of this problem may be of personal and practical value to him; his interest will consequently be aroused to a considerably higher degree, and he may actually enjoy solving the problem. Figures 1 and 2 show the problem "dressed up" in these two different ways.

Figure 3 shows a problem of the type mentioned earlier in this discussion, one that is of perhaps almost zero practical value, but the solution of which will require some pretty straight thinking, and which will drive home some rather important facts decidedly worth-while to know. The problem deals with that perennial of electronic problems, the half-wave rectifier. Few, indeed, are the applications of half-wave rectifiers in practice, but nothing explains the fundamental principles of rectification better than a thorough study of half-wave circuits. In this circuit, which an engineer in the laboratory of the Cutler-Hammer Company came across quite accidentally, a source of alternating current feeds a resistive load, such as a Mazda lamp, over a half-wave rectifier. If the source of alternating current is, for instance, 110 volt, and the lamp is also rated at 110 volts, the lamp will of course burn with considerably reduced brightness, and the d-c meter connected in series with the lamp will indicate the average current through the lamp.

An inductance is now connected parallel to the lamp, as shown. The inductance is supposed to be of low value, perhaps 0.1 henry, and is assumed to have negligible resistance. The problem is to predict what will happen to the current in the branch containing the lamp, that is, if anything does happen, and if so, to explain why it does take place. The drop in the rectifier in the forward direction is assumed as negligible, whereas the resistance in the opposite direction is assumed to be infinite. In order to leave no illusion about the fact that there is more behind the problem than meets the eye, the answer to the first question is given herewith: The reading of the meter in series with the lamp will drop, but the brilliancy of the lamp will increase. If this sounds unbelievable, a setup of the circuit in the laboratory is suggested. The answer to the second question, that is, the explanation of this phenomenon, is left to the reader.

But it would take a genius indeed to think up problems of the kind just presented; one discovers such problems now and then by the intervention of a kind fate, and not through

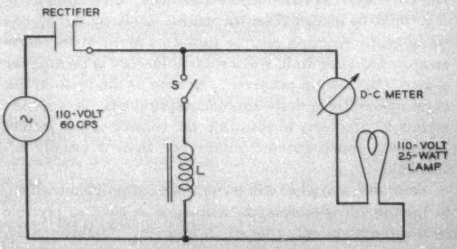


Figure 3. Problem

In the circuit shown, an a-c source of 110 volts, 60 cycles per second, is connected to a series combination of a half-wave rectifier, a d-c meter, and a 110-volt lamp. An inductance L of about 0.25 henry can be connected parallel to the lamp, by closing switch S. Before switch S is closed the meter will read a certain amount and the lamp will burn with a certain brightness

1. *Do you think that closure of switch S will have any effect on the conditions in the lamp branch?*
2. *State your reasons for whatever answer you give to the foregoing question*

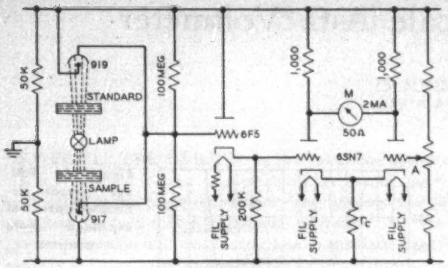


Figure 4. Problem

In the circuit shown the two phototubes (characteristics assumed to be identical) both receive a light flux of 0.5 lumen. Under this condition the meter M (2 milliamperes full scale, zero-center, 50 ohms resistance) is to read zero

1. Are the two phototubes placed correctly or should they be interchanged?

2. To what value of potential must point A be adjusted to make M read zero? (Use data sheet for 6SF5)

3. If each triode section of the 6SN7 is to carry six milliamperes under balanced conditions, how large must r_c be made?

4. By how many per cent must the light falling on one phototube change from the specified value of 0.5 lumen, to make the meter read full scale?

5. Why should the 6F5 cathode follower stage be operated with reduced filament voltage?

one's own efforts. For the majority of problems we are forced either to create them out of thin air as well as we can, or to modify an actual problem encountered in our work for this purpose. But why modify the problem? If at all possible, a problem ought to illustrate as many points as possible, and this usually can be accomplished only by modifying some practical problem. If a problem of reasonable practicability can be made to show, for instance, the combination of a photoelectric circuit, a cathode follower, and a balanced phase inversion circuit, the student will not only acquire familiarity in working out individual components, but will also see, how and for what purpose they will be combined. Such an example is shown in Figure 4, which incidentally represents a circuit actually used for the observation of small differences of turbidity in two sample solutions. While this is a problem presented in connection with the lectures on photoelectric cells, whereas the student at that point in the course has already solved some problems dealing with cathode followers and phase inversion circuits, the combination of the new subject, that is, photocells, with the components he is already familiar with, not only fortifies his knowledge of the latter, but will show him how these components can be put to practical use. A student working diligently and conscientiously on this problem, giving an answer to each of the questions, cannot help obtain a respectable knowledge of the subject.

Coal Gas Obtained by Electric Burning

Fuel gases from coal as it lies underground in its natural seams has been successfully obtained by sending an electric current through the coal, *Science News Letter* reported in its issue of October 15, 1949. This accomplishment was made by the University of Missouri in co-operation with the Sinclair Coal Company near Hume, Mo.

As described by Dr. J. D. Forrester, chairman of the university's mining department, the process consists of making drill holes from the surface into a seam of coal lying below. Iron pipes are inserted into the holes to serve as electrodes. Connected with the electrodes is a series of pipes a few feet above ground through which the gas flows when it is generated.

A current of considerable voltage, controlled by a water rheostat, is sent down through the electrodes into the seam. In the process of passing through the coal and overcoming its electrical resistance, the coal is heated and begins to give off oil-saturated gas. This gas comes to the surface through the pipes that serve as electrodes. These pipes are 20 to 40 feet apart.

After the coal bed becomes sufficiently heated so that it will burn and yield other gases, the electric current is stopped and air or oxygen is pumped into the coked and porous coal seam to sustain further combustion. This continues the supply of gases from the actual gasification of the underground coal.

The gases produced by this so-called electrocarbonization process can be used as raw material from which to make synthetic gasoline, or can be converted into a heating fuel. The gas produced is similar to the coke furnace gas of surface plants. Field tests were preceded by laboratory experimentation during which it was proved that coal can be turned into gas by an electric current. Both laboratory and field work was done by Erich Sarapuu, a research fellow of the University of Missouri's School of Mines and Metallurgy.

Several test runs on coal layers have been made during the past year. Some oil-tar has been collected at Hume along with the gas. In addition, laboratory investigation with oil-sand has resulted in the production of crude oil, as well as gas.

Fuel gases from underground coal are being obtained by the United States Bureau of Mines in experimental work at Gorgas, Ala., in a joint project with the Alabama Power Company. No electric current is used, however, in the gasification process. Underground burning is employed.

Two holes are sunk into the coal seam, and fire started in one by use of an incendiary bomb. Air under pressure is forced in to feed and spread the fire, and the gases of combustion are driven by the same air pressure to the second hole from the top of which they are captured.

A New Expanded Scale A-C Voltmeter

N. P. MILLAR
ASSOCIATE AIEE

IN MANY POWER SYSTEM voltage measurements the measurement problem consists of detecting and indicating accurately a variation of plus or minus one volt or less from a given reference voltage. The use of the conventional zero-left, a-c, moving-iron, or electrodynamic voltmeter does not provide enough of a deflection to read with any degree of certainty, since, for example, a one volt variation from 120 volts on a 250-degree-scale concentric-type switchboard voltmeter represents approximately 3/64 inch of arc. There is then a need for an expanded scale voltmeter that produces a scale length per volt within the range of normal voltage variation of at least four times that of the conventional voltmeter.

Two general engineering approaches that have been used in the development of expanded scale voltmeters are

(*a*). A modification of the basic instrument mechanism.

(*b*). The use of standard mechanisms with impedance networks, the outputs of which vary as some function of the voltage to be measured.

A simple example of a modification of the basic instrument mechanism is the suppressed zero a-c voltmeter. A few of the major reasons why this method of scale expansion has proved unsatisfactory are

(*a*). Loss of natural zero setting.

(*b*). Sluggish pointer action within the expanded scale region due to low torque gradient.

(*c*). Need for frequent calibration checks with a carefully controlled voltage reference.

There are many examples of expanded scale voltmeters which function in response to the variation of an impedance in some kind of a network, but one of the chief disadvantages that characterizes this type of device is component stability. Also, many require an auxiliary source of power for operation which complicates design and increases cost.

The most practical solution to the scale expansion problem now available is the use of an iron-core saturable reactor in combination with an instrument of the electrodynamic type. Of all the known types of nonlinear circuit components, the iron-core reactor gives the most stable and reproducible performance characteristics. If a voltage is applied across such a reactor, the exciting current will vary in a nonlinear fashion with the voltage. Any suitable a-c milliammeter connected in series with this reactor to measure the exciting current could have its scale calibrated in terms of volts. The scale distribution then would correspond to the nonlinear variation of the exciting current.

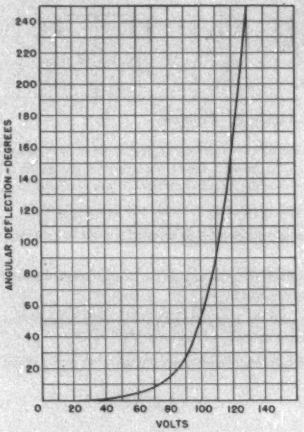
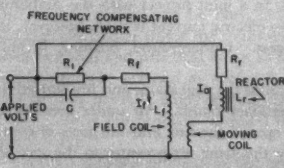


Figure 2. Voltage versus deflection curve of expanded scale voltmeter

In a practical design of an expanded scale voltmeter the nonlinear current of the reactor has been used to energize the moving coil of a standard electrodynamic wattmeter mechanism. Both the field and moving-coil circuits are connected in parallel to the voltage source to be measured. The primary reasons for using the wattmeter mechanism instead of the a-c milliammeter are to keep the instrument volt-ampere burden comparable to standard voltmeter burdens, and make it easier to apply a resistance-capacitance network for frequency compensation of the reactor.

The successful application of a saturating core reactor to a standard electrodynamic wattmeter mechanism has resulted in a new design of an expanded-scale voltmeter with improved reliability and an accuracy of one-half per cent of full scale rating. One-half-volt variations can be detected and read easily in the expanded region from 90 to 130 volts where 130 volts represents full scale. Frequency error is compensated to within plus or minus one-fourth per cent of full scale per cycle from 105 to 130 volts and over a plus or minus five cycle variation from a reference frequency of 60 cycles. The error due to wave-form is less than one per cent of full scale when the voltage source contains both third and fifth harmonics of five per cent each.



R_f, L_f—Resistance and inductance of field coil
R_r, L_r—Resistance and inductance of reactor
R_1, C—Resistance-capacitance network for frequency compensation
I_f—Field current, amperes
I_a—Moving coil current

Figure 1. Schematic diagram of expanded scale voltmeter

Digest of paper 49-161, "A New Expanded Scale A-C Voltmeter," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Power Supplies for Coaxial Systems

H. H. SPENCER

TYPE "L" BROAD-BAND carrier telephone systems over coaxial cables require repeaters spaced every eight miles or less along the cables. The large number of repeaters involved makes it desirable to transmit 60-cycle power from main and terminal stations to auxiliary repeaters over the same coaxials as used for carrier transmission. The power circuit shown in Figure 1 for a typical span of about 100 miles between adjacent power sending stations involves primaries of powerpacks at each repeater arranged in series with the inner conductors of the coaxials to form a series loop from each sending station. Power separation filters at each repeater separate the carrier frequencies for amplification and return to the coaxials without affecting or being affected by the power circuit. The power packs are individually adjusted to give proper filament and plate power based on a constant current system with a line current of approximately 500 milliamperes. This current is regulated at the sending end by means of an automatically-controlled motor-driven variable transformer which raises and lowers the voltage as required to compensate for changes in line impedance with temperature or for variations in the power source voltage. Automatic regulation provides protection against overload such as might occur if a coaxial should open or become short-circuited. Where the overload is insufficient to blow the supply fusing, the controls reduce the line current to normal by dropping the voltage to the necessary value. Where the short circuit is near enough to the main station to blow a supply fuse, the control circuit functions to turn the variable transformer to minimum voltage so that replacement of the blown fuse cannot cause a line current surge.

The 230-volt a-c supply for the coaxial power circuit is provided from continuously-operated alternators rather than direct from the commercial service to reduce the effect on carrier transmission caused by power service fluctuations and outages. The alternators are self-excited and driven normally by induction motors from the commercial service and during emergencies by d-c motors from the station 130-volt battery. With stable power supply frequency, induction motor speeds are practically constant, and as the sets are self-excited and the loads practically constant, the alternator output voltage is normally held within close limits and is affected very little by commercial power voltage variations.

The d-c motor is connected to battery whenever the alternator is operating but is kept from supplying any appreciable power while the a-c motor is driving by the insertion of a current limiting resistance in its armature circuit. The field of the motor is connected to the battery side of this resistance and the setting of the field resistance is such that the cross electromotive force across the armature is practically equal to the battery voltage. Accordingly, when fast acting relays short-circuit the resistance in the armature circuit to cause the d-c motor to take over the drive, there is little or no inrush of armature current and therefore little change in alternator output. The d-c motor speed is unregulated and varies with the battery voltage. As the battery is held within close limits to meet station load requirements, the alternator output during emergency operation is within a range for which the power control circuits can maintain regulated coaxial cable current.

Alternators are usually furnished on the basis of one alternator per pair of coaxials. Sets rated at 1.5 or 2.5 kva are usually used with a maximum of five in a station feeding power in two directions, one for each pair of coaxials in an eight coaxial cable plus a common standby emergency alternator arranged to replace automatically any regular alternator in trouble.

These power supplies are completely automatic for use in remote unattended stations, and because of this, they include alarms which are transmitted to an attended station to indicate abnormal conditions. Alarms are given if the coaxial current exceeds its normal limits, if drive is transferred to the d-c motor, if alternators fail along with other power plant alarms such as low battery voltage, or battery fuse failure. Engine alternator standby for the commercial service is generally furnished and in unattended stations the engine sets are automatically started and controlled.

Digest of paper 49-156, "Power Supplies for Coaxial Systems," recommended by the AIEE Committee on Communication and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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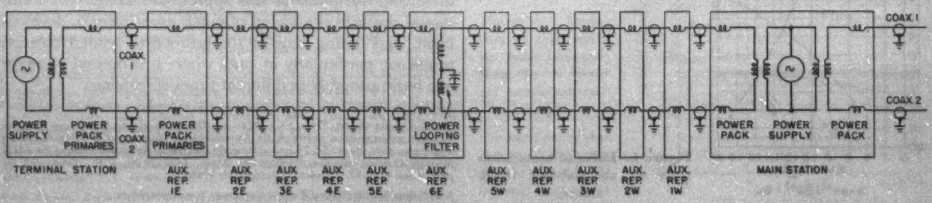

Figure 1. Power transmission circuit

Response of Thermal Demand Meters

J. S. NELSON
MEMBER AIEE

THE TIME OF RESPONSE of demand meters is of critical importance wherever a demand charge is made for electricity. In demand meters of the mechanical block-interval type the demand interval is usually governed by a gear train and resetting mechanism connected with some synchronous device, such as a clock motor, and response time presents no special problems in design. The response time of thermal meters depends upon less easily evaluated constants and coefficients. This article examines these factors and presents equations from which the time of response may be calculated.

Specifically, these equations pertain to a thermal meter designed with opposed, self-heated, bimetallic spirals connected by a shaft. The effect of relative heat flow from the two opposing bimetallic actuators upon the time constant of a thermal demand meter is explored. To accomplish this, the time equation for a device responding to the difference in temperature of two similar bodies connected by a thermal shunt and each supplied with constant heat input is derived for the general case wherein the heat flow from one of the bodies is not equal to that from the other, that is, a heat flow ratio other than unity.

This approach has yielded valuable information pertaining to the effect of differential heat escape upon response time. By making use of these equations, a linear-scale meter (for watt demand) and a square-law scale meter (volt-ampere demand) have been designed for the same response time to meet the same meter code requirement without the necessity for different designs of bimetallic spirals. The significance of this becomes clear when it is recalled that response time is defined in the Code for Electricity Meters as time to reach 90 per cent of ultimate indication (in watts or volt-amperes). Hence, if two meters having different scale distribution are to meet the same code requirements, their physical response times, in terms of angular deflection, must differ correspondingly.

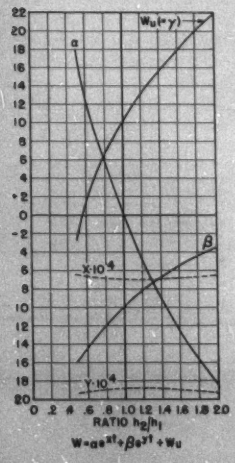

Figure 1. Effect of heat-escape ratio on thermal-unit coefficients

It is hoped that these equations may find application also to the design of integrating or indicating instruments employing thermal storage such as I^2T indicators for welding energy, small panel instruments of the bimetallic spiral variety, and differential thermometers composed of pairs of resistance-temperature detectors, bourdon tubes, thermocouples, or bimetallic actuators.

The following pair of equations is set up for the condition of initial equilibrium of the thermal unit, with pointer indicating zero, and with ambient temperature constant:

$$H_1dt - Q(\theta_1 - \theta_2)dt = h_1(\theta_0 + \theta_1)dt + Md\theta_1$$
$$H_2dt + Q(\theta_1 - \theta_2)dt = h_2(\theta_0 + \theta_2)dt + Md\theta_2$$

In these equations, H denotes heat input; Q, the thermal transfer coefficient of the shaft; θ, temperature increment of a spiral; θ_0, initial temperature above ambient temperature; h, thermal conductance from a spiral to ambient; and M, thermal capacity of each spiral. The subscripts denote values pertaining to spirals number one and number two, respectively.

The solution of these equations is given as

$$W = \alpha e^{xt} + \beta e^{yt} + \gamma,$$

wherein W, the difference in temperature between spirals, and t, time, are the only variables. The constant, γ, is evaluated as the ultimate temperature difference and the constants α, β, x, and y represent combination of the primary design constants h, H, Q, and M. These constants are evaluated and curves are presented showing the effect upon performance of varying the design parameter h_2/h_1.

Four categories of heat-escape ratio are of interest; they are as follows:

Unity ratio: A simple logarithmic curve of temperature difference with time results.

Small ratio: Temperature difference will lessen or reverse with time.

Large ratio: Response time is increased, but time constant is rendered complex.

Ratio slightly larger than unity: Response time may be controlled with the least effect upon other characteristics.

The use of the equations presented, permitting the intelligent variation of the appropriate design constants, should result in the saving of much experimental, development, and testing time in the solution of related thermal problems, particularly in cases where it is desired to adapt one basic assembly to different times of response.

Digest of paper 49-160, "Heat Flow Ratio as a Design Parameter in Thermal Demand Meters," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Conductivity in Semiconductors

K. LARK-HOROVITZ

This article is a summary of the material on the nature of the conductivity in semiconductors presented at the AIEE Summer General Meeting in a Symposium on Electrical Properties of Semiconductors and the Transistor. Previous articles in the series covered rectification and photoeffects in semiconductors.*

WHILE it is well known that the electrical conductivity of metals decreases with increasing temperature, there is a number of metallic-looking substances which show an entirely different behavior. These substances show low conductivity at low temperature, the conductivity increases as the temperature is raised, reaches a maximum, decreases again, and finally increases another time and much more sharply when a higher temperature is reached.

This behavior can be completely understood on the assumption that the number of current carriers in these substances is dependent on temperature. These materials are called, because of their behavior, semiconductors.[1–3]

At low temperatures, the number of carriers is small; ideally it should be zero at absolute zero and the semiconductor would become an insulator. As the temperature increases, a greater number of carriers becomes available by dissociation from impurity centers and the conductivity increases. When all of the carriers from impurity centers have been released, their number remains constant until new carriers are released from another source at higher temperature. In the meantime with increasing temperature the probability of collision with the atoms present in the lattice of the semiconductor becomes more frequent, the mean free path decreases, and as a consequence the resistance increases with temperature rise. There is, however, the possibility that at higher temperatures more electrons might be freed from the semiconductor itself and not from impurities. These so-called intrinsic electrons are available in far greater numbers than the total number of carriers which are freed from impurity centers (one per impurity center) and as a consequence the resistance at elevated temperatures decreases very rapidly (Figure 1). It is possible that one might find electron acceptors, instead of donators, in the semiconductor. These acceptor impurities have the peculiar quality, not of giving off electrons with rising temperature, but of taking up electrons. As a consequence, there remains a "hole"* in the electron distribution. This "hole" has the properties of a "positive" electron and an effective mass which may differ from the mass of the free electron. Thus it is possible to create a conductor of electricity which conducts by particles which behave as free electrons, except that their effective mass may differ from the mass of the electron and that their charge is opposite in sign. Such a conductor seems to conduct by positive charges.

Silicon and germanium are elements of the fourth group of the periodic table with the same crystal structure as diamond and they have, respectively, 5.2×10^{22} and 4.5×10^{22} atoms per cubic centimeter. It has been found that the addition of impurity elements of the third group, such as boron, aluminum, gallium, and indium, give defect or *P*-type (hole) conductivity. Additions of impurity elements from the fifth group, such as nitrogen, phosphorus, antimony, and arsenic, give excess or *N*-type (electron) conductivity.[16–22]

It is possible to determine the sign of the carriers in vari-

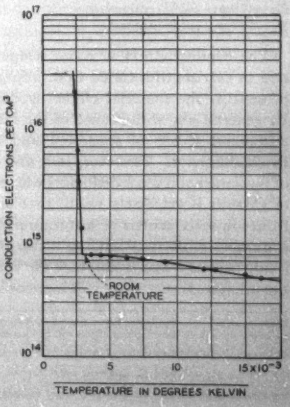

Figure 1. Variation of conductivity with temperature for a typical semiconductor sample

The rapid rise of conductivity at high temperature occurs in the intrinsic range of the material

*The importance of the "holes," their origin and behavior, are discussed in greater detail in the article on transistors.

** Under the action of a magnetic field, electrons or holes are deflected transversely; this deflection continues until a transverse electromotive force is produced such that the electric field E_y just compensates for the action of the magnetic field. From then on, the carriers flow as if no magnetic field existed. This means that, as soon as a steady state has been reached, the total transverse force on a carrier is zero. This condition can be written simply as: $e[E_y + (v_z H_x)/c] = 0$, where v_z is the velocity of the carrier in the direction of current flow. But $v_z = \mu_z E_z$, where E_z represents applied electric field and μ_z mobility (see footnote ††). Due to Ohm's law, electric field and current density are connected by $i_z = \sigma E_z$, where σ is the conductivity. Hence the first equation may be rewritten:

$$E_y = -(v_z H_x)/c = -(\mu_z E_z H_x)/c = -(\mu_z i_z H_x)/(\sigma c) = -(i_z H_x)/(nec)$$

since $\sigma = ne\mu$, where n is the number of carriers per unit volume. The Hall constant R_H is defined as $E_y/(i_z H_x)$, that is, electric field normal to the current flow per unit magnetic field and per unit current density; hence $R_H = \pm 1/(nec)$, with the + used for hole conductors and − for electron conductors. Therefore $1/R_H$ is a direct measure of the number of carriers produced. For semiconductors $1/(nec)$ must be multiplied by a factor $3\pi/8$ due to the Maxwell distribution of carrier velocities; hence $n = 7.37 \times 10^{22}/R_H$.

A compilation based upon the following three papers presented at section *A* of the Symposium on Electrical Properties of Semiconductors and the Transistor held during the AIEE Summer General Meeting in Swampscott, Mass., June 20–24, 1949: "The Conductivity of Silicon and Germanium as Affected by Chemically Introduced Impurities," G. L. Pearson, Bell Telephone Laboratories, Inc.; "Nucleon-Bombarded Semiconductors," K. Lark-Horovitz, Purdue University, Lafayette, Ind., and session chairman; "The Control of the Conductivity of Oxide Semiconductors by Admixture of Other Oxides," N. C. Jamison, Phillips Laboratories.

* See *Electrical Engineering* for October 1949, pages 865–72, and for November 1949, pages 937–42.

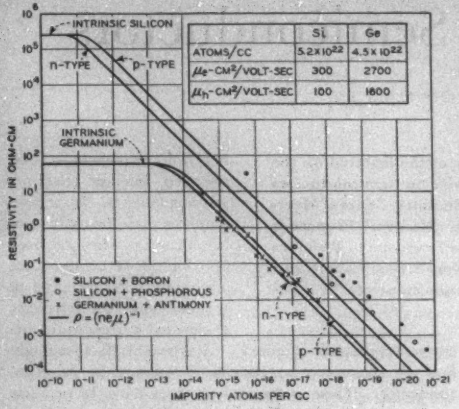

Figure 2. Dependence of resistivity at 300 degrees Kelvin upon the impurity content of silicon and germanium alloys

ous ways. One method** is to measure the transverse electromotive force (V_y) produced in a material if a current (I_x) flows through the material and a magnetic field (H_z) is applied normal to the direction of current flow (Hall effect).

A second simple way of determining the sign of carriers is the determination of the sign of the thermoelectric power, and finally, a third method is by observation of the direction of rectification, which usually can be predicted from the sign of the Hall effect: a *P*-type semiconductor in contact with a metal electrode will have a current flow in the opposite direction from the one observed in an *N*-type or electron-carrying semiconductor.†

It will be useful here to note the number of intrinsically available carriers in the elementary semiconductors and the following figures are given for comparison (all at room temperatures):

Si—10^{10} per cubic centimeter
Ge—10^{14} per cubic centimeter
Te—10^{18} per cubic centimeter

The conductivity†† at room temperature and below is due to carriers dissociated from impurity atoms which are present in the material either by design or accidentally. In general, any disturbance of the lattice will produce an additional source of scattering and therefore a decrease in conductivity. However, it is also possible, in the case of insulators and semiconductors where the intrinsic number of carriers is extremely small, that dissociation of carriers from impurity centers or lattice imperfections will produce a number of carriers large as compared to the number already present; and in this case the conductivity, in spite of the additional scattering will increase rather than decrease.

† The so-called inversion layers first discussed by Schottky and others which play such an important role in the transistor effects will be discussed in the transistor symposium.

†† $\sigma = ne\mu$ where n is the number of carriers, e the electronic charge, and μ the mobility, the velocity per unit field E. ($ma = eE$; $ma/eE = \mu = \frac{s}{m}\frac{l}{v} = \frac{el}{mv}$, or $v/E = \mu = \frac{s}{m}\frac{l}{v} = \frac{el}{mv}$ where l is the mean free path and v the average thermal velocity.)

Both of these effects have to be taken into account to understand fully the behavior of semiconductors. At higher temperatures the number of carriers released from the energy states of the semiconductor itself will play the most important role, and these intrinsic carriers are always produced in pairs, electrons (*N*-type) and holes (*P*-type). The number of carriers present at any temperature depends on the activation energy necessary to thermally excite carriers in the bound state (either impurity or intrinsic). It is therefore possible to write for the conductivity of any semiconductor the following equation: $\sigma = \sigma$ (intrinsic) $+ \sigma$ (impurity). With the impurity content usually present, the first term is negligible as compared to the second at room temperature. For example, the intrinsic conductivity of pure silicon at room temperature is 4×10^{-6} (ohm-centimeter)$^{-1}$ and the addition[8] of one boron atom for each million silicon atoms increases this to 0.8 (ohm-centimeter)$^{-1}$, a factor of increase of 2×10^{5}. In germanium the intrinsic conductivity at room temperature is 1.67×10^{-3} (ohm-centimeter)$^{-1}$. It is therefore possible to write for the conductivity of any semiconductor the following equation: $\sigma = \sigma$ (intrinsic) $+ ne\mu$, where n is the number of carriers released by impurity atoms. Figure 2 shows the dependence of room temperature conductivity of silicon and germanium upon impurity content.

The mean free path due to collison of the carriers with the lattice atoms is approximately proportional to $1/T$, and since the mobility is given by $\frac{el}{mv}$ one would expect that the mobility due to lattice scattering is proportional to $T^{-3/2}$.

Although it usually has been assumed that lattice scattering is primarily responsible for the resistivity in semiconductors, detailed analysis of the results obtained in germanium and silicon show that this cannot be correct.[16,17] It has been shown[16,18] that the resistivity of germanium alloys is due to two causes:

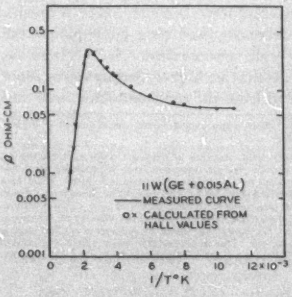

Figure 3. Comparison of calculated and measured resistivities for an aluminum - doped germanium sample

The calculated points are computed from Hall coefficient values and constants characteristic of the germanium lattice

1. Scattering of electrons or holes by the lattice; this produces a resistivity

$$\rho_L = DR_H T^{3/2}$$

where D is an experimentally determined constant characteristic of

the semiconductors, R_H is the Hall coefficient of the alloy sample, and T is the absolute temperature in degrees Kelvin.

2. Scattering by singly ionized impurity centers, giving a resistivity

$$\rho_I = A(kT)^{-3/2} \ln\{1+\alpha(kT)^2 d^2\}$$

where A and α are constants characteristic of the semiconductor and d is one-half the distance between impurity centers, or about $1/2n^{-1/3}$. Because of its dependence on n, d is calculated from the Hall coefficient, and so ρ_I may be found by measuring R_H. In the derivation of this formula for impurity scattering it is assumed that:

(*a*). Each impurity center releases one carrier and that the total number of impurity centers available can therefore be determined from the Hall curve.

(*b*). The ratio of electron to hole mobility is constant as temperature changes; for both germanium and silicon it is found that $\mu_e/\mu_h \approx 3$. The ratio of the effective mass of a hole to the electron mass is then $m_h/m_e = (\mu_e/\mu_h)^{2/3} \approx 1.6$.

(*c*). The dielectric constant of germanium is about 17 and of silicon about 13.

Figure 3 shows that the theory just described can successfully account[16,18] for the resistivity of a semiconducting sample throughout the impurity and intrinsic ranges. At very low temperatures quantum statistics must be taken into account and, with this extension, agreement between theory and experiment is retained.[5,12,13] However, the presence of other scattering effects, such as those due to grain boundaries or the existence of lattice vacancies, is indicated, particularly if one wants to account quantitatively for the resistivity of silicon samples or of tellurium samples.

Quite recently it has been possible*,[21] to grow single crystals of pure germanium and of germanium alloys, and in these crystals the effect of single grain boundaries can be studied and scattering due to polycrystalline grain boundaries can be eliminated. By carrying out electrical resistivity and Hall effect measurements on such samples (both *N*-type and *P*-type) at high temperatures for which lattice scattering predominates, it was found that electron and hole mobilities in germanium single crystals are given by the relation $\mu_e = 1.5\ \mu_h = 1.35 \times 10^7\ T^{-3/2}$ square centimeter per volt-second. At room temperature these mobilities amount to 2,600 and 1,700 square centimeters erp volt-second, respectively, considerably higher than the foregoing values quoted for polycrystalline samples. Also the ratio of electron to hole mobility at any given temperature is smaller than the value quoted and indicates a mass ratio $m_h/m_e = (\mu_e/\mu_h)^{2/3} = 1.18$ for germanium.

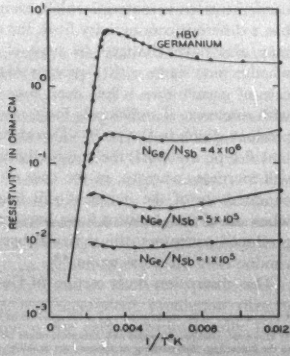

Figure 4. Resistivity versus temperature for germanium-antimony alloys, showing variation in magnitude and shape with changing antimony concentration

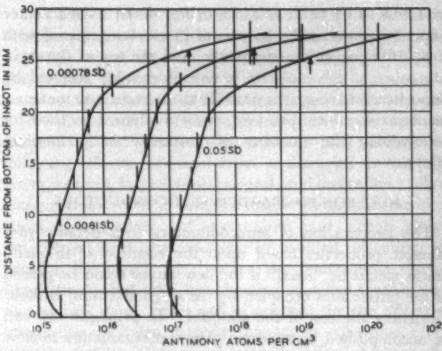

Figure 5. Number of antimony atoms per cubic centimeter as a function of the distance from the bottom of the melt

The length of the experimental lines indicates the width of the slice before powdering. The arrows show the average concentration of Sb atoms which were placed in the charge before melting

Because of the small number of intrinsic carriers at room temperature, addition of impurities even of the order of 10^{-3} to 10^{-6} per cent by weight can change the conductivity of a semiconductor in a measurable and reproducible way (Figure 4). It is not possible to determine quantitatively the distribution of such small amounts of impurities by ordinary chemical or spectro-chemical methods. In the case of aluminum special spectroscopic methods have been used.[16] However, it is possible to use radioactive isotopes of suitable impurities, such as phosphorus[16] and antimony,[20] and to study the distribution of the solute with a Geiger counter.

By using the radioactive isotope of antimony (Sb^{124}) such experiments can be carried out.[20] The amounts of antimony added to germanium were 0.054, 0.0081, and 0.00078 per cent. Radioautographs indicate that the antimony concentration varies exponentially with the depth in the ingot, being greatest at the top, which was the last portion to freeze. Geiger counter measurements on specimens from various positions give a quantitative analysis of the antimony distribution (Figure 5). Hall effect measurements on the same specimens show that in the saturation region of the impurity range each antimony atom produces one conduction electron (Figure 6). Having correlated the Geiger counter and Hall-effect measurements, one is justified in determining the concentration of impurities in nonradioactive ingots from the flat portion of the Hall curve. As an example, Hall effect measurements on an *N*-type high back voltage germanium ingot to which no impurity had been deliberately added show an excess

* Such crystals were prepared by H. C. Theurer, Bell Telephone Laboratories, and W. E. Taylor, Purdue University.

of 1.8×10^{14} per cubic centimeter donor over acceptor impurity atoms at the bottom of the melt compared with 1×10^{15} per cubic centimeter near the top of the melt. Moreover, if the mobility is not appreciably affected by impurity scattering, it is possible to use resistivity measurements at room temperature as an analytical method for determining the quantity of antimony in germanium alloys.

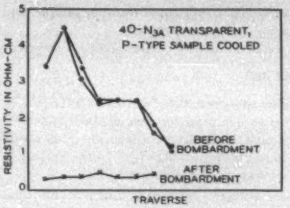

Figure 7. Effect of bombardment upon the resistivity profile obtained by measuring the voltage drop between a movable probe and one end of the germanium sample

NUCLEON-BOMBARDED SEMICONDUCTORS

The preparation of semiconductors with definite predictable properties based upon the addition of impurity atoms would be "ideal" if the new atoms could be placed at the lattice sites occupied by the original atoms, without disturbing the rest of the material. In principle this can be accomplished by exposing pure semiconductors to slow (thermal) neutrons, which are absorbed with the emission of gamma rays and produce radioactive nuclei, which disintegrate, leaving stable new atoms in place of the original semiconductor atoms and their isotopes. In the case of germanium the number and type of isotopes is quite well known, and it is also known that transmutation can lead to the formation of new atoms, namely gallium, which will produce *P*-type conduction, and arsenic, which will produce *N*-type conduction.*

The balance between the two types of new impurity centers produced will be the factor to determine whether the final material will conduct by holes or electrons. The answer as to which one of these processes will predominate is determined by the efficiency with which the target nuclei interact with the nucleons, that is, by the so-called activation cross section, σ_A.

In general, for any interaction of nucleons with target nuclei, one can write

$$N_e = nvt \times \sigma_p \times n_A \times p_i \times w$$

where N_e is the number of events produced, nv the number of particles striking unit area per second, nvt, the integrated flux, σ_p, the cross section for the process in square centimeters, n_A, the number of target atoms per cubic centimeter, p_i, the isotopic abundance of the atoms used, and w, a factor describing how many secondaries accompany the primary effect.

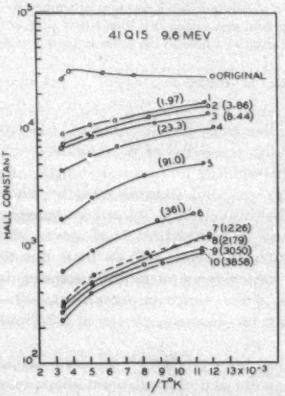

Figure 8. Hall coefficient as a function of temperature for a germanium sample in its original condition and after various amounts of deuteron irradiation

Figures in parentheses indicate the number of deuterons per square centimeter $\times 10^{-11}$

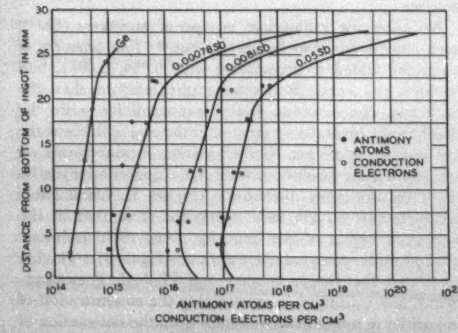

Figure 6. Correlation between antimony atom and conduction electron densities

The solid circles represent the densities of antimony atoms as determined by radioactivity measurements. The open circles represent the densities of conduction electrons as determined by Hall effect measurements

For transmutation, w is equal to 1, but for displacement due to elastic collision with fast particles, w can be of the order of several hundred.

Prolonged exposures, in the Oak Ridge nuclear reactor, of germanium samples with known numbers and types of carriers has led to material which, even after heat treatment, has a different conductivity from the original material and may also have changed its type of carrier. No matter whether one starts with *P*-type or *N*-type material, in the case of germanium it has been found that bombardment with nucleons, if sufficiently long, always produces an end product which is *P*-type.[19] Therefore, in the case of original *P*-type material, the conductivity upon bombardment will increase; whereas, in the case of *N*-type material, the conductivity of the material will first decrease and then, when all of the electrons have been removed by the newly produced acceptors, the material becomes *P*-type and the conductivity increases again.**

The absorption cross section of Ge for slow neutrons as

* The number of Se atoms produced is too small to be of appreciable influence.

** However, charged donators and acceptors might be now present and so contribute to the scattering, thus tending to decrease the mobility.

given in the literature leads to the prediction that the production of N-type material by transmutation will prevail, in contradiction to the experiments. However, recent investigations of the cross section of separated germanium isotopes by H. L. Pomerance of the Oak Ridge National Laboratory indicate that the final material should be P-type and that the number of P-type centers produced is approximately two per cent of the total integrated neutron flux which has fallen upon the material.

For a total flux density of 10^{18} or more, the number of effective P-type centers produced by transmutation is of the order of magnitude of the number of impurity ions usually found in semiconductors (prepared for practical applications) and can be used to produce "ideal" impurity semiconductors provided the original material is homogeneous and single crystals are used.

It is possible to check these predictions experimentally by exposing a germanium semiconductor of known number of carriers in the nuclear reactor. One measures the integrated neutron flux, waits for the decay of any radioactivity (to avoid transient effects), heat treats the material at 450 degrees centigrade in a vacuum (for a period of several hours), and measures the Hall effect: the number of carriers calculated from the Hall effect is then $n = n_i \pm n_o$, where n_i is the number of excess P-type carriers produced by transmutation and n_o is the number of carriers present originally. The number has to be subtracted if n_o is the number of electrons, and it has to be added if n_o is the number of holes. Some high-resistivity P-type and N-type samples were exposed in the Oak Ridge reactor some time ago, and from the Hall effect it was found that the total number of transmutations calculated from the newly measured cross section agrees within ten per cent with the number actually found by Hall effect measurement, again substantiating the theoretical prediction that, in the ideal semiconductor, for each substitutionally introduced impurity center one current carrier is produced.

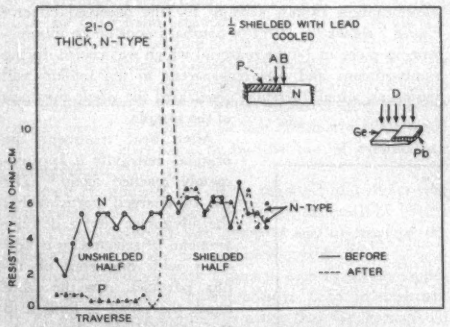

Figure 9. Resistivity profile of thick N-type Ge sample

The left half was bombarded with deuterons and the right half was shielded with lead foil. Notice the high resistance of the P-N barrier

The most striking effect of the irradiation of semiconductors with nucleons (neutrons, protons, deuterons, alpha particles) is not the effect of transmutation, which only plays a part upon prolonged irradiation with neutrons, but an effect which is due to the interaction of the heavy particle with the nuclei of the target as it passes through the material. Bombardment with nucleons may produce the following effects: transmutation as discussed in the foregoing, heating, lattice displacements, and ionization. Heat treatment is known to produce drastic changes in the electrical characteristics of germanium and silicon alloys. An over-all heat treatment can be avoided, of course, by keeping the sample at constant low temperature during irradiation. However, local heating, so-called spot heating, as assumed many years ago to account for the effects of irradiation on living material, cannot be ruled out. The most important effect seems to be the effect of lattice displacements: the passage of high-speed particles through the material will produce collisions with lattice atoms and may displace them, thus creating lattice vacancies and interstitial atoms. A displaced atom may receive enough kinetic energy to cause additional displacements and this may produce an avalanche of perturbations in the lattice. In the case of irradiation with charged particles, ionization may produce some transient changes in conductivity, depending upon the ionizing power of the passing particles.

A deuteron beam of 1 microampere per square centimeter falling on a sample corresponds to 6×10^{12} particles striking one square centimeter of the surface per second. A comparable number of neutrons is expected to interact with a substance placed in a reactor. The number of carriers originally present is of the order of 10^{14}–10^{18} per cubic centimeter, depending upon the purity of the sample. Large effects due to bombardment therefore can be expected in a

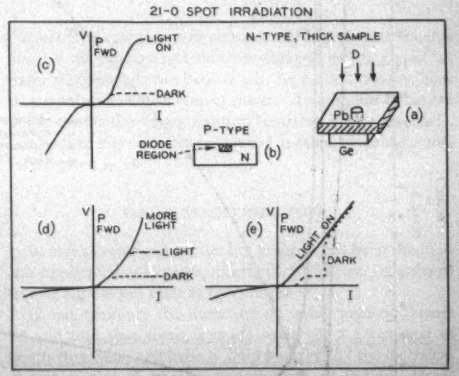

Figure 10. Photo-diode produced by spot irradiation of N-type germanium with deuterons

A—Irradiation arrangement
B—P-type island surrounded by N-type germanium
C, D, E—Sample current-voltage characteristics in the dark and under illumination

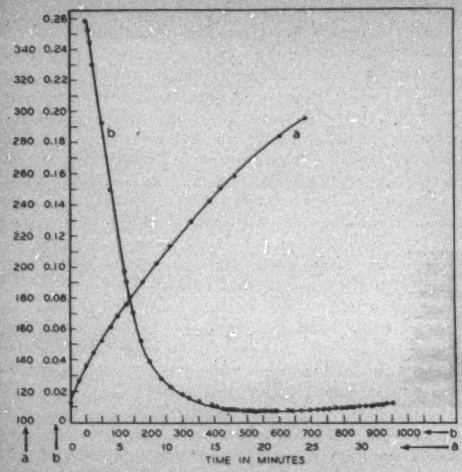

Figure 11. Curve A shows the effect of neutron irradiation in increasing the conductance of a P-type germanium sample; curve B shows that irradiation first reduces the conductance of an N-type germanium sample to a minimum and that additional irradiation produces a slowly rising conductance as the material is converted to P-type (the time variable refers to time of exposure to radiation)

comparatively short time. The first experiments which were carried out with the Purdue cyclotron showed the expected large influence of nuclear irradiation on semiconductors, and in the case of germanium it was possible to show that in *P*-type germanium the conductivity increases with bombardment by either deuterons or alpha particles from the cyclotron or even by irradiation with alpha particles from naturally radioactive substances. In *N*-type germanium the resistance first increases upon bombardment, the material then converts to *P*-type, and from there on the resistance decreases upon further bombardment. There are some transient effects,[8] indicating self-healing, but in general the effect is a permanent one. This is quite different from the effect of high-speed electron bombardment, which, as has been shown by preliminary experiments,[18] produces an effect which disappears in a few microseconds. In the case of charged particles, the loss of energy is primarily due to ionization, but it is possible to calculate classically the primary interaction with the target atoms due to Coulomb scattering, and one can estimate roughly the number of secondaries produced. In the bombardment with deuterons and alpha particles the effect of transmutation can be neglected, since the measured resistivity indicates that the impurity centers produced by transmutation cannot account for the observed effect.[19] Figure 7 shows the effect of bombardment on an inhomogeneous piece of *P*-type material which was cooled during bombardment and was transparent to ten million volt deuterons, which therefore penetrated the whole thickness of the sample.

After heat treatment the original resistivity is approximately reached again.[9] The use of charged particles has the advantage that a definite area can be selected for irradiation with deuterons or alpha particles. On the other hand, the effect is limited to the range of the particles in the material, which, in the case of germanium and silicon, is only a fraction of a millimeter and necessitates, therefore, the preparation of special samples. That the observed effects are due to the production of new carriers, and particularly due to the production of acceptors, is seen from Figure 8, which indicates the changes in Hall effect and therefore in the number of carriers as a function of irradiation. In this particular experiment, 9.6 million volt deuterons were used, and the numbers indicate the number of deuterons per square centimeter which actually fell on

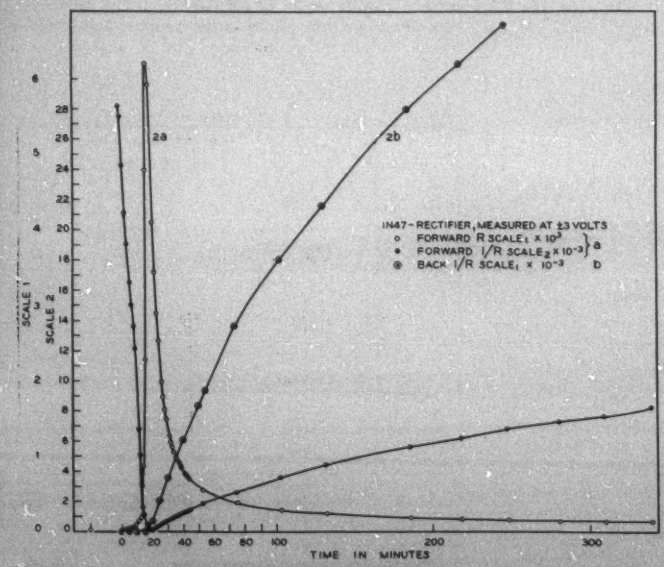

Figure 12. Effect of neutron irradiation upon the forward and back current, at ±3 volts, through a germanium rectifier

the sample. With increasing irradiation, the number of carriers increased steadily, but at the same time a change in the slope of the curve was also observed, indicating a different mechanism of dissociation of carriers from the one which is found in impurity centers introduced chemically.

The fact that charged particles can be limited to a definite striking area and to the range in the material can be used in a simple way to test qualitatively for the effect of irradiation. It is possible, for instance, to probe the surface with a metal wire and show by the change in rectification characteristics that the material has changed from N to P. It is also possible in a similar way to show that the effect extends only to the range of the particles in the material. It is finally possible to shield a certain portion of the material and in this way to produce in one and the same material, as Figure 9 shows, adjacent parts, one conducting by holes and the other conducting by electrons. The P-N barrier produced in this way acts as a rectifier, as a photoelement, and as a photoconductive device as detailed experiments have shown.[6]

It is also possible to use spot irradiation[8] (Figure 10) to produce artificially effects such as have been observed in some of the materials before, namely the so-called "photodiodes" (photocells with a point contact, Figure 10C, D, or trigger cells, Figure 10E).

On the other hand, irradiation with neutrons produces a volume effect, and because of the steady flux in the nuclear reactor, it is possible to measure the change in conductivity during irradiation continuously and in this way to follow the transition from N to P, which is proved (after a proper cooling period, so that radioactive effects are eliminated) by either the Hall effect or by the use of rectification measurements.[10,11]

Figure 11 indicates the effects observed and shows that it is indeed possible to produce P-type materials by irradiating N-type material with neutrons and to increase the conductivity of P-type material considerably.

A number of other semiconductors such as silicon, copper oxide, selenium, and tellurium have been investigated. In all of these semiconductors other than Ge investigated so far, it has been found that upon irradiation the conductivity is diminished regardless of the type of carriers originally present in the material. The effect is particularly striking in silicon, where, for instance, a sample originally $\sim$ 0.5 ohm-centimeter reached a resistivity of the order of 10,000 ohm-centimeters after neutron irradiation of some days. It has been shown[9] both by electrical and optical (infrared) measurements, that this is due to the production of some deep lying impurity levels absorbing both electrons and holes.

The experiments on irradiation of semiconductors by nucleons also have been extended to the irradiation of rectifiers,[14] a type of investigation which promises to be particularly interesting because of the possibility of shifting the Fermi level in the rectifying material and of observing rectification characteristics as a function of irradiation. (See Figure 12.) One can say, therefore, that the irradiation of semiconductors with nucleons can be used to produce in germanium an ideal P-type semiconductor due to prolonged exposure to slow neutrons. By exposing semiconductors to fast neutrons, deuterons, and alpha particles, it is possible to produce permanent changes which persist at room temperature but which can be healed out by heat treatment at elevated temperatures. Irradiation enhances defect conduction in germanium (creating P-type material), but leads to high resistance material in other semiconductors investigated so far.

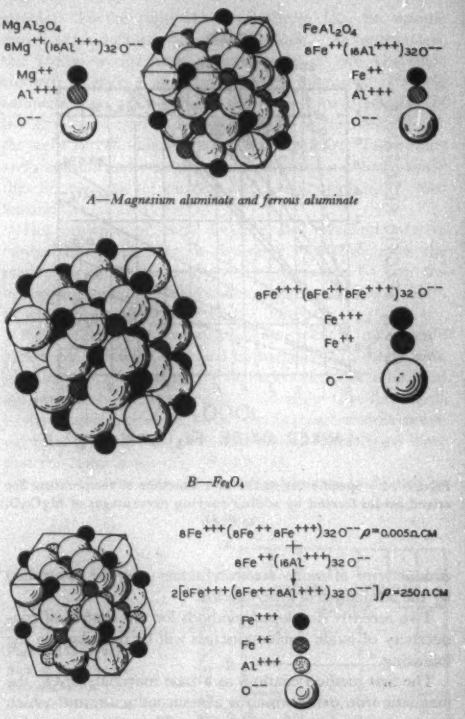

Figure 13. Unit cells of spinel structure

OXIDE SEMICONDUCTORS

In recent years a great deal of progress has been made in the application of oxides, particularly for use in current regulating devices such as thermistors.

If one examines the literature on oxide semiconductors he will find that there is much material, a great deal of conflicting data, and little to help him predict the electrical characteristics of new semiconducting materials. However, it is possible to start with a certain oxide, which may have either quite high or quite low conductivity, and by the addition of a carefully chosen oxide and by sintering, form a mixed crystal which has a conductivity in the desired intermediate range. In this sense it may be said that the

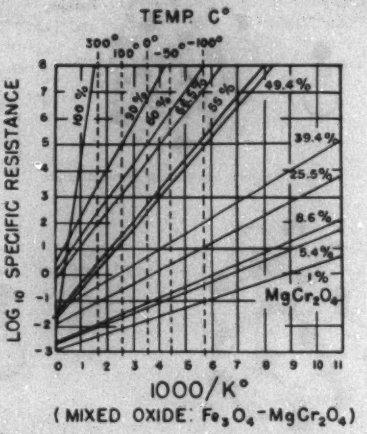

Figure 14. Specific resistance as a function of temperature for mixed oxides formed by adding varying percentages of $MgCr_2O_4$ to Fe_3O_4

conductivity of oxide semiconductors may be controlled by the admixture of other oxides.

Two recently developed methods for the control of conductivity of oxide semiconductors will be described in the following.*

The first method employs as a base material, Fe_3O_4, the magnetic iron oxide which is a semiconductor, and which has a very low specific resistance. The molecule consists of two trivalent Fe ions, one divalent Fe ion, and four oxygen ions.

The reason for the low resistivity of Fe_3O_4 has long been an interesting subject for conjecture. About 13 years ago a tentative explanation[24] was proposed which now has experimental verification. The explanation involves the crystal structure of the material and it will be explained as simply as possible. The material Fe_3O_4 has the general spinel structure and Figure 13*A* shows the struture of magnesium aluminate, the mineral spinel from which the structure takes its name. The unit cell or elementary cell shown is the smallest sample of the material which shows the structure. It is seen that there are Mg ions at the midpoints of the edges of the cube and that the Al ions are arranged along the diagonals. (We shall speak of all atoms as ions even though it is realized that the binding may not be wholly ionic.) For our purpose the arrangement of the Al ions along the diagonals is the important thing to note. It should be said, in addition, that each of the Al ions is surrounded by the same number of oxygen ions and with the same configuration. The Al ions are thus in equivalent ion sites.

As a second example of the spinel structure, at the right

* Both of these methods have been the outgrowth of a comprehensive research program at the Philips Research Laboratories in Eindhoven, Holland. These methods are due to the efforts of Verwey, Haayman, and Romeijn and their coworkers at Eindhoven. Some results have not before been presented in English and a brief résumé which appeared in a Dutch periodical[25] has escaped notice.

Table I. Variation of Electrical Properties With Composition of Mixed Oxide Formed by Adding $MgCr_2O_4$ to Fe_3O_4

Per Cent $MgCr_2O_4$ in Fe_3O_4	ρ Ohm-Centimeter at 27C	ϵ in (e.v.) $\rho=\rho_0(\exp)\frac{\epsilon}{KT}$	B in (1/ Degrees Kelvin) $\rho=\rho_0(\exp)\frac{B}{T}$	Temp. Coeff. of Resist. (Per Cent/ Degrees Centigrade) at 27 Degrees Centigrade
0.9	1.6×10^{-2}	0.07	810	0.9
5.4	4.0×10^{-2}	0.08	930	1.0
8.6	6.3×10^{-2}	0.09	1,040	1.15
25.5	6.3×10^{-1}	0.10	1,160	1.3
39.4	3.2	0.13	1,510	1.7
49.4	1.6×10^{2}	0.21	2,440	2.7
54.6	3.2×10^{2}	0.23	2,660	3.0
67.4	1×10^{3}	0.31	3,600	4.0
80	4.4×10^{3}	0.33	3,800	4.3
90	6.2×10^{3}	0.36	4,170	4.6

the ions of ferrous aluminate are identified. Here the trivalent Al ions again prefer the positions along the diagonals; we shall have occasion to refer to this material later.

Figure 13*B* shows the unit cell of the basic material which is used in the first method. The unit cell contains 16 trivalent iron ions, eight of which are located at the midpoints of the sides of the cube and eight at sites along the diagonals; the eight divalent ions are also situated along the diagonal ion sites.[26]

It is now easy to see why Fe_3O_4 has such a low conductivity. There are located in adjacent equivalent lattice sites, on the average, alternate divalent and trivalent iron ions. Hence, it should be relatively easy to transfer an electron from one Fe^{2+} to one Fe^{3+} ion and if this action should occur in a chain the passage of electrons through the material should be easy and the conductivity should be high.[24]

It has been suggested that the conductivity of Fe_3O_4 might be diminished by breaking the chains. Figure 13*C* shows the ion positions in a mixed crystal of Fe_3O_4 and $Fe\,Al_2O_4$. If an equal molal part of ferrous aluminate is added to Fe_3O_4 and the mixed crystal is formed, the ion sites along the diagonals are occupied on the average by alternate

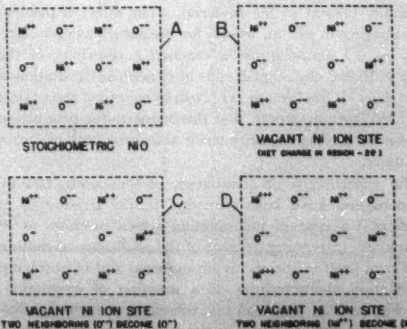

Figure 15. Arrays of nickel and oxygen ions in a single layer of the nickel oxide lattice

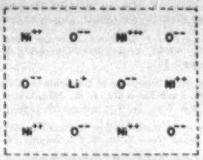

Figure 16. Lithium substitution for nickel in the nickel oxide lattice

Fe^{2+} and Al^{3+} ions. Since aluminum always has the valency three, the conduction possibility involving valence changes of neighboring ions is largely ruled out. It is found that the resistance of the mixed crystal is greater than that of Fe_3O_4 by a factor of about 50,000.[27]

The illustration just given was presented because it is simple in that the only new element involved by admixture was Al, which is always trivalent. It is not necessary that the divalent ion of the admixed oxide be iron or that the trivalent ion be one which occurs only with the valence three. Figure 14 shows the effect of the additions of magnesium chromate, which also has the spinel structure, to Fe_3O_4. The log of the specific resistance is plotted as a function of 1,000 times the reciprocal of the absolute temperature. It is seen that the slopes of the curves and thus the temperature coefficients of resistance increase with the magnesium chromate content.[27]

The variation of the electrical properties as a function of composition may be better seen from Table I. It is seen that the specific resistance may be varied by more than a factor of 10^8 and also that the temperature coefficient of resistance increases with increasing magnesium chromate content.

Thus, by the first method, certain oxides having the spinel structure may be added to Fe_3O_4 with the result that the Fe^{2+}—Fe^{3+} conducting chains are broken down and the conductivity is substantially decreased.

The second method has a wider scope in that it is not restricted to a single structure and the basic material may be one of a large number of oxides having high specific resistance. To this oxide may be added another oxide with a resulting decrease in resistivity even though the added oxide may also have a high specific resistance.

As an introduction, it is helpful to consider the mechanism of conduction in nickel oxide. It has long been known that nickel oxide is not ordinarily stoichiometric, that is, that the number of nickel atoms in a small sample is not exactly equal to the number of oxygen atoms in the sample. There is usually a tendency toward a nickel deficiency. Samples which are nearly stoichiometric have a high specific resistance, whereas those which have a nickel deficiency have a considerably lower resistivity, perhaps lower by several powers of ten.

The mechanism of conduction in nonstoichiometric nickel oxide has been described by a simple picture.[7] Figure 15 shows arrays of nickel and oxygen ions in a single layer of a crystal. At the upper left we have stoichiometric NiO, with equal numbers of Ni and O atoms in a small sample. To the right above in Figure 15, the sample shown has a deficiency of one nickel ion. As represented, this region would have a net charge of two electronic charges, which is a situation not to be tolerated. Possible compensations are shown in the lower two diagrams; at the left two oxygen ions might become monovalent and at the right two Ni ions might become trivalent. Theoretical and experimental results indicate that there is little doubt that for each nickel vacancy two neighboring nickel ions assume the trivalent state.

The presence of both divalent and trivalent ions in equivalent lattice sites in the same crystal suggests the possibility of increased electrical conduction. Upon the application of a field the transfer of electrons from divalent to trivalent ions would establish a current.

Now let us consider what might be expected to happen if nickel ion sites were occupied by monovalent lithium ions, (divalent nickel ions and monovalent lithium ions have approximately the same radii). In order that the region have no net charge either an oxygen ion must become monovalent or a nickel ion become trivalent. There is evidence that the latter is the case (Figure 16).

Figure 17 shows how the specific resistance is affected by

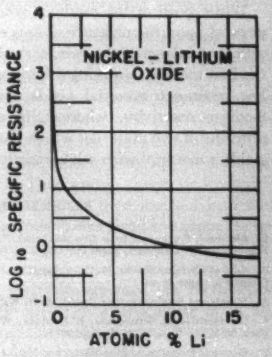

Figure 17. Variation of specific resistance with percentage of lithium substituted for nickel in the nickel oxide lattice

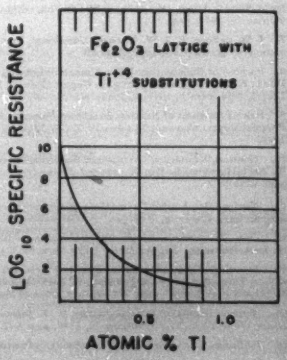

Figure 18. Variation of specific resistance with percentage of titanium (Ti^{4+}) substituted for iron (Fe^{3+}) in the Fe_2O_3 lattice

the substitution of lithium ions in the cation lattice. Whereas stoichiometric nickel oxide has a specific resistance in the neighborhood of 10^9 to 10^{10} ohm-centimeters, the 15 per cent substitution of lithium ions for nickel ions reduces the resistivity to less than one ohm-centimeter.[38]

It is also possible to force ions in a basic lattice into a lower valence state, thus bringing about an increase in the conductivity. For instance, Fe_3O_4, which has the hematite structure, has a specific resistance of about 10^9 ohm-centimeters. If this material is sintered with TiO_2 the resulting mixed crystal has a much lower specific resistance. In this case the decrease in resistivity is attributed to the substitution of tetravalent titanium ions for trivalent iron ions; thus some of the iron ions are forced into the divalent state and the possibility of electrical conduction is established. The variation of specific resistance with titanium content is shown in Figure 18.

It may be noted that whereas the substitution of lithium for nickel in nickel oxide results in a *P*-type semiconductor, the substitution of titanium for iron in Fe_2O_3 yields an *N*-type semiconductor. This is in accordance with the general rule that if a metal forms several oxides, the one in which the metal occurs in its lowest valence will be a *P*-type semiconductor and that in which the metal occurs in its highest valence will be an *N*-type semiconductor.

While both of the methods which have been described depend upon the presence of ions of the same metal having different valencies, the two methods are quite distinct. In the first method, sintering a high resistance material with a low resistance material yields a material with an intermediate resistivity, whereas, in the second method the sintering of two materials which have high specific resistance yields a material with a low resistivity.

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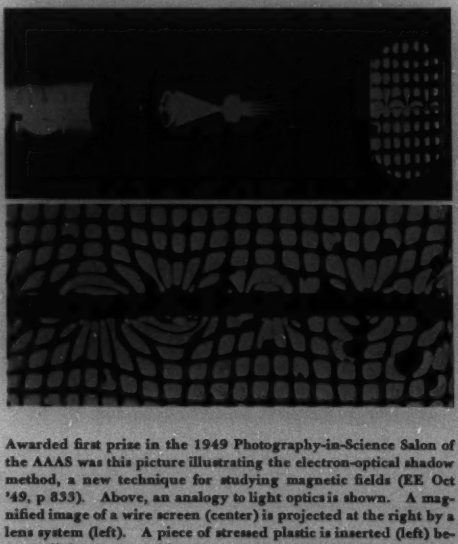
Prize Photo Shows Shadow Method



Awarded first prize in the 1949 Photography-in-Science Salon of the AAAS was this picture illustrating the electron-optical shadow method, a new technique for studying magnetic fields (EE Oct '49, p 833). Above, an analogy to light optics is shown. A magnified image of a wire screen (center) is projected at the right by a lens system (left). A piece of stressed plastic is inserted (left) between light source and lens system, resulting in a distorted image of the wire screen. In the electron-optical shadow method, the magnetic field is introduced between electron source and electron lenses. Below is a typical pattern. From the distortion of the mesh image, field intensity is computed.

Fourier Coefficient Harmonic Analyzer

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THE SEPARATION of a complex curve into its constituent sine and cosine curves of proper amplitude and phase by means of a Fourier series analysis is well known, and this method is frequently used in many branches of engineering and mathematics. All who have ever made such an analysis know that the computation for the Fourier coefficients can be very tiresome and expensive from the point of view of time and effort.

In the past 50 years several efforts have been made to construct special-purpose computing machines to calculate rapidly the Fourier coefficients. The machine reported in this article was likewise constructed to make such rapid calculation, originally for a large quantity of data which had to be analyzed for harmonic content. It is believed that this machine accomplishes its purpose far more ably than any of the previously designed analyzers.

The Fourier Coefficient Harmonic Analyzer, affectionately termed "FOCOHANA," can be considered to be a special-purpose continuous-variable type of differential analyzer, designed to solve the following integrals:

$$A_0 = \frac{1}{\pi}\int_0^{2\pi} F(\theta)\,d\theta \tag{1}$$

$$A_n = \frac{1}{\pi}\int_0^{2\pi} F(\theta)\cos n\theta\,d\theta \tag{2}$$

$$B_n = \frac{1}{\pi}\int_0^{2\pi} F(\theta)\sin n\theta\,d\theta \tag{3}$$

These terms are recognized as the coefficients of the Fourier series

$$F(\theta) = A_0/2 + \sum_{n=1}^{\infty} [A_n \cos n\theta + B_n \sin n\theta] \tag{4}$$

The computations of equations 1, 2, and 3 are carried out using standard 5-inch ball-and-roller integrators. The entire machine is self-contained and no change gears are required over the full range of 100 harmonics.

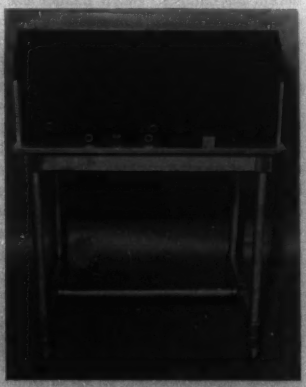

Figure 1. Over-all view of the harmonic analyzer

Figure 2. Ball-and-roller mechanical integrator partially opened

Operation of the new harmonic analyzer is quite simple. The curve to be analyzed is drawn on a piece of graph paper having a 10-inch length for the independent variable and a maximum of five inches, peak to peak, for the ordinate or dependent variable. This curve sheet is wrapped around a plastic cylinder which is then inserted into the machine. When the machine is energized the input curve table revolves and the operator tracks the curve manually. Once the completed curve has been tracked, the machine shuts off automatically and counters read the coefficients A_0, A_n, and B_n, with the subscript n depending upon an initial setting. Each time the curve is scanned another set of coefficients is calculated. In this analyzer n can vary from zero to 100 or a range of 100 harmonics can be investigated. Some of the salient features of the new harmonic analyzer are as follows:

Number of harmonics which can be investigated—100.

Change gears—none; analyzer is totally self-contained.

Type of input—curve is drawn on graph paper, cylindrical curve table.

Type of output—sine and cosine coefficients read on counters.

Method of tracking curve—visual, with manual control.

Time to scan for each harmonic—two to seven minutes depending on curve.

Figure 1 is an over-all exterior view of the analyzer. Figure 2 shows a ball and roller type of mechanical integrator partially opened.

Digest of paper 49-163, "A New Fourier Coefficient Harmonic Analyzer," recommended by the AIEE Computing Devices Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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A New Instrument Mechanism

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A NEW instrument mechanism has been developed which is remarkable for its small size and weight compared to conventional instruments. It is suitable for use in d-c electric indicating instruments in either portable or panel devices. The instrument is capable of moderately high sensitivity and is most readily adaptable to applications where expanded scale distribution is desirable.

This new instrument mechanism differs from conventional construction in that the magnetic material is entirely within the locus of the moving coil. A soft iron ring surrounds the locus of the moving coil, completing the flux path as well as providing magnetic shielding. This construction differs from the conventional arrangement in which the magnetic material is entirely external to the locus of the moving coil and a soft iron core is provided to complete the magnetic circuit.

Since the entire section of sintered Alnico V magnet is much closer to the moving coil than the conventional external magnets, a large portion of the leakage flux actually threads the moving coil and thereby is useful in producing torque. This arrangement has resulted in 50 per cent utilization of the total flux compared to 10 to 25 per cent in conventional instruments. The optimum shape of the moving coil of an internal magnet instrument is larger in diameter than that of the conventional external magnet design.

An internal magnet instrument is used in the exposure meter developed by General Electric for use with the Polaroid Land Camera. In this particular design, several innovations in construction were introduced. To reduce the thickness of the instrument to a minimum, the pivots and control springs of the instrument were mounted inside the moving coil. This arrangement allowed maximum thickness of the magnet as limited by the over-all thickness of the instrument case. The use of the internal magnet reduced the weight of the magnetic material from 2 ounces in conventional instruments to 0.2 ounce in this instrument. The reduction in size of the mechanism permitted further reduction in the size of the over-all case so that the complete device weighed about one-fourth that of a comparable conventional exposure meter.

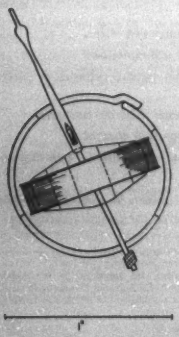

Figure 1. Schematic diagram of internal magnet instrument mechanism showing magnet inside the locus of the moving coil

Instrument designs employing internal pivots have in the past required special tools and techniques for adjusting the position of the jewels within the soft iron core. In the instrument developed for Polaroid, the jewels were mounted on a U-shaped bracket and their position was adjusted by flexing the bracket at one corner by means of a screw which pulled the ends of the U together. This arrangement provided external adjustment with internal pivots with the same facility and precision possible with the conventional external pivot construction.

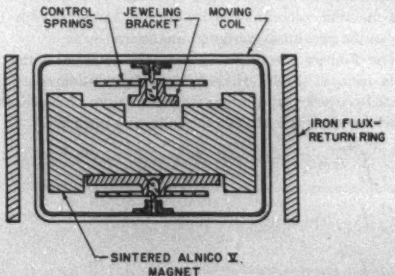

Figure 2. Longitudinal section of instrument mechanism showing profile of sintered magnet in relation to moving coil

The internal magnet instrument has the following inherent advantages: much smaller size and weight; more efficient utilization of magnetic material because a larger percentage of the total flux is effective; expanded scale distribution; and self-shielding in two dimensions and less sensitivity to stray fields in the other direction.

The internal magnet design also has certain limitations: to increase the flux density, the moving coil must be made larger in diameter so as to accommodate a larger magnet; the larger moving systems associated with internal magnets have higher inertia and hence greater response time than conventional instruments of equal sensitivity; at full scale where logarithmic distribution requires low flux density, the magnetic damping is limited; and linear scale distribution is more difficult to attain.

Digest of paper 49-162, "A New Instrument Mechanism," recommended by the AIEE Instruments and Measurements Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Not scheduled for publication in AIEE *Transactions*.

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A 66-Kv Subtransmission Plan

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IN CHICAGO a new type of subtransmission system was adopted recently to provide for the expansion in load which is being experienced. This system utilizes a subtransmission voltage of 66 kv, which was formerly used only at transmission levels. The higher voltage provides a more desirable and economical arrangement for the present conditions encountered on the Chicago system.

In the early development of the power system in the city of Chicago, all the generators were located inside the city and relatively close to the load. The subtransmission for the 60-cycle load consisted of underground lines at the generated voltage (12 kv) direct from the generating station to the distribution substations, and the various generating stations were sometimes interconnected by these same 12-kv lines. Later the 12-kv interconnections were eliminated, and the 12-kv subtransmission system was separated into independent zones, each supplied from a major 12-kv switchhouse originally located at a generating site. These zones were then interconnected by a 66-kv transmission system. The switchhouses which were constructed under this plan were relatively large in size, with space for 40 to 60 12-kv line positions. A considerable amount of capacity was concentrated at each location, which led to the use of phase-isolated construction for all major stations.

Subsequent developments have stimulated consideration of a new plan of subtransmission.

1. It has been increasingly necessary to develop generating sites outside the city. Power from these sites is transmitted into Chicago at high voltage, and is made available to the 66-kv interconnecting system in the city. This arrangement makes more favorable the use of 66 kv as a subtransmission voltage within the city.

2. The present 12-kv lines average about 4 miles in length, and the longest lines extend 8 to 10 miles from the switchhouse. With the rapidly increasing load density, continued subtransmission from these sites at 12 kv involves considerable costs, and the need for a higher voltage is indicated.

3. In recent years there has been an extensive development of factory-assembled switchgear, which has many attractive features. Switchgear of this type, in a price class which makes it suitable for substation use at 12 kv, has been made available in interrupting capacities as high as 500,000 kva.

In the light of these developments various studies have been made of the economies of extending the 66-kv system for subtransmission purposes. As the need for 12-kv switch positions has increased, consideration has been given to the use of small 66/12-kv substations of simplified construction, which would be supplied from 66-kv lines. This arrangement has several advantages, such as: the smaller substation permits a closer match between system requirements and actual construction; extending the 66-kv system closer to the load reduces the amount of cable required for subtransmission purposes; the problem of cable congestion around large switchhouses is reduced; small installations inherently have a lower value of short-circuit current, permitting the use of low interrupting capacity equipment; substations are more adaptable to supervisory control than large switchhouses due to the simplicity of the layout and the smaller amount of load being supplied from the station; and the smaller 66/12-kv substations provide improved reliability for the 12-kv system by reducing the number of 12-kv lines in one location.

As a result of these and other considerations, several small 66/12-kv substations are planned for the Chicago area. These stations will be supplied by 66-kv lines which will operate radially without 66-kv bussing at the substations, and each line will supply two transformers located at different stations. The 66-kv cable will be 3-conductor, oil-filled, 650,000 circular mils, and the transformers 3-phase units, with a self-cooled rating of 20,000 kva. The line and transformer capacities have been co-ordinated closely to make full use of the available capacities. Also, the transformer size is such as to limit the fault current in each substation to less than 500,000 kva.

At each substation there will be three transformers connected into a ring bus. The 12-kv bus is designed for maximum electrical separation between busses and transformers with a minimum use of 12-kv circuit breakers. There will be 16 outgoing 12-kv lines at each station.

The relay protection provided for the new subtransmission system is conventional in most respects. Overcurrent relaying is provided on the 66-kv and 12-kv lines, and differential protection is provided for the transformers and busses. Because the substation transformers are connected to the lines without 66-kv circuit breakers, the transformer differential relays actuate a remote trip circuit to clear the remote ends of the lines. This trip circuit is incorporated at small additional cost in the pilot wire cable which is required for the oil-pressure alarm system for practically the entire length of the 66-kv cable.

Studies have been made of the relative economy of 66 kv and 12 kv for subtransmission for underground systems such as exist in Chicago. These studies show that 66 kv is more economical than 12 kv for subtransmission distances above 3,000 feet when power is available at the generating station either at 66 kv or 12 kv. If power is available only at 12 kv, the 66-kv system is more economical for distances above 15,000 feet. If power is available only at 66 kv, 66 kv is more economical for any distance.

The gain in economy and reliability resulting from the use of the system described is evidence that time devoted to the planning of the subtransmission portion of a system may be well justified.

Digest of paper 49-172, "A 66-Kv Subtransmission Plan for a Metropolitan Area," recommended by the AIEE Committees on System Engineering and Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Overcurrent Study on a Rural System

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GOOD service continuity with the least possible outlay is a major problem on every rural distribution system. Sectionalizing the primary line is accepted practice today to improve continuity. The problem is to formulate numerically the benefits obtainable with different types of equipment and to find better protective methods.

An overcurrent investigation was conducted during 1944, 1945, 1946, and 1947, with these objectives in mind, using the 7200/12, 470Y volt 4-wire multigrounded Y rural distribution system of the Central Electric Cooperative of Parkers Landing, Pa. Characteristics of this system included long radial circuits, penetration into less densely populated areas resulting in wider separation of lightning protective equipment, and other factors which magnify the overcurrent protection problem.

This system feeds an area of approximately 40 by 60 miles in the hilly country along the Allegheny River in northwestern Pennsylvania, where lightning, wind, trees, and other hazards to good service are of typical severity. Rural Electrification Administration type of line construction is employed, using practically only one make of electric equipment. In 1944, there were 1,015 miles of primary line (87½ per cent single-phase line-to-neutral) feeding 4,178 consumers through 3,100 transformers. East and west sections of the system were fed by separate 900-kva transformer banks, supplied from the West Penn Power Company's 25-kv line, with two feeders on each section.

A study of the system requirements showed the need for co-ordinated overlapping operation of recloser and fuses on the entire system. These should be arranged so the recloser clears all nonpersistent faults with only a momentary outage but in the case of a persistent fault would cause a fuse to isolate only a small faulted section of the line. In order to sectionalize the lines adequately, the recloser has to be co-ordinated with sectionalizing fuses between reclosers, branch fuses, subbranch fuses, and transformer fuses (of both external and internal types), all connected in series for sequential operation.

Actual co-ordination studies were made on this rural system assuming the use of all types of reclosers co-ordinated with fuses for overlapping protection. These studies showed that the recloser which opened twice instantaneously, then locked closed until the proper fuse blew, and then reset automatically, was the only one that would meet all of the system requirements. As no commercial design was available in 1944 the existing General Electric *FP-119* reclosers on this rural system were modified to provide the lock-closed function.

Data were obtained from the reports of service crews and from automatic General Electric *PM-13* oscillographs connected on two of the four main feeders. In analyzing the data it was found that treating the four 3-phase feeders as 12 single-phase circuits provided the most accurate information on the operation. Also it indicated that such treatment of a 3-phase circuit having predominately single-phase loads would aid in obtaining the best results in applying protective equipment. The frequency of occurrence of different causes of faults and the exposure, measured in the number of faults per mile of primary line, was shown to be similar to other published data. This indicated that the results obtained in this investigation should be of value to all operators of rural systems.

Single-phase circuits of 40 to 60 miles in length showed from 3.1 to 13.0 hours outage per consumer per year, even with the co-ordinated overlapping fuse–lock-closed recloser protection. This is higher than can be tolerated on rural systems. It appeared from data on a 25-mile-long feeder, that if it had been equipped with the improved fuse-recloser protection, a desirable standard of two hours outage per consumer per year might be obtained.

The fuses and lock-closed reclosers co-ordinated for overlapping operation showed very substantial reductions in hours outage per consumer per mile of line per year varying from 70 to 90 per cent. Also the savings in restoration expense obtained was 32.8 per cent in man-hours and 26.8 per cent in mileage traveled. This 28.5 per cent saving in cost will justify an investment in reclosers and fuse cutouts of $3,400 with an annual charge of 15 per cent or $12,750 with a four per cent annual charge. This would either carry one-third of the $10,500 cost for the protective equipment required on the system investigated or would result in a net profit of $90 per year over the carrying charge, depending on the financing.

The oscillograph measurements of fault currents were checked against the calculated values indicating that the assumption of 40 ohms for fault resistance for calculating minimum fault currents was more than ample and might have been 30 ohms.

Inrush currents following prolonged outages, measured on the two feeders on which the oscillographs were located, never exceeded 2.5 to 3 times the normal current. Thus they were not troublesome in restoring service. However, trouble in reclosing the circuit on another feeder (without the oscillographs to record the currents) was solved by shunting the recloser with a fuse. The lock-closed recloser performs a similar function automatically if an impulse current should lock it closed. Thus a system protected by fuses and lock-closed reclosers should be trouble-free from inrush currents preventing service restoration following prolonged outages.

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Power Supplies for Home Television Receivers

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There are two differences between the power supplies found in an ordinary radio and those found in a home television receiver: the more complex low-voltage supply needed in the latter, as well as the presence of a high-voltage supply for the cathode-ray tube. This article discusses the several methods of providing such power for a television set.

TWO FEATURES of the d-c power supplies required in home television receivers distinguish these d-c supplies from those in ordinary radios. The features are the relative complexity of the low-voltage $B+$ and bias supply; and the presence of a high-voltage power supply, ranging in voltage output from 2,000 to 30,000 volts.

The high-voltage power supply is needed for the cathode-ray tube. The current requirement of this supply ranges from 100 to 600 microamperes; therefore, the design of such supplies presents problems quite remote from usual high-voltage designs of power engineering.

B+ AND BIAS SUPPLY

Several factors are responsible for the more elaborate low-voltage supply in a home television receiver. First and most obvious is the fact that a television set has considerably more tubes than a radio. The smallest home television receiver available commercially has 15 tubes, with the number of tubes increasing up to 42 for a projection-type combination radio-phonograph television set. Power requirements range from 25 watts to 180 watts in radios, whereas the smallest television sets consume 100 watts, and the larger combination models draw as much as 550 watts.

Another factor adding to the complexity of $B+$ and grid bias power supplies in television receivers, is the higher quality performance required by the video amplifying circuits. The ear will accept an amount of distortion in audio signals that the eye would find unbearable in video presentations. Thus, a five per cent hum at 120 cycles from a radio is readily masked by the music or sound; however, a five per cent hum on the intensity of the picture is quite noticeable and objectionable.

This high-quality performance requires considerably more filtering than is encountered in radio $B+$ supplies. The additional filtering is furthermore mandatory for the deflection circuits, where very small 60-cycle or 120-cycle ripple may interfere with proper sweep-circuit synchronization. A third distinctive feature of television receiver low-voltage power supplies is the requirement for a plate-to-cathode voltage of 500 or more volts for proper beam deflection in low cost transformerless sets employing electrostatic deflection picture tubes.

The foregoing features are best illustrated by reference to typical power supplies in home television sets. Figure 1 shows a $B+$ and bias supply for a television set employing a 10-inch magnetic deflection kinescope. There are two *5U4G* rectifiers employed, this being the largest high-vacuum rectifier designed for home radios. Extremely heavy capacitance filtering is used, in addition to the filter choke. Thus a π-type filter with 120 microfarads in each leg is the basic $B+$ filter.

In order to center the picture vertically and horizontally, sources of adjustable direct current must be available for the deflection coils. This direct current is taken from the 20-ohm center-tapped potentiometers labeled "horizontal centering control" and "vertical centering control." Because the deflection current flows through these resistors, large filtering capacitors must be used across them, or noticeable deflection frequency ripple will appear at the 275-volt $B+$ point.

Figure 2 shows a typical low-voltage power supply for

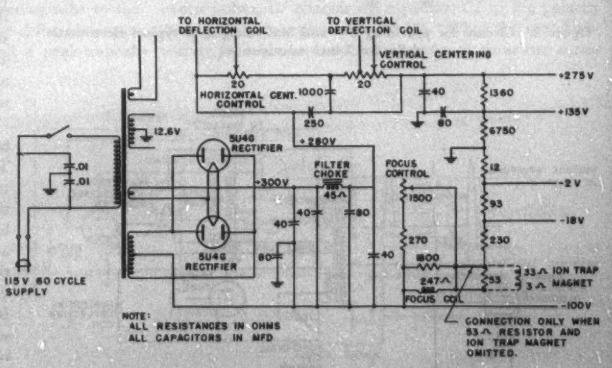

Figure 1. Circuits for providing B+ and bias voltages, and deflection coil centering currents, in typical magnetic deflection 10-inch television set

Essentially full text of paper 49-258, "Low-Voltage and High-Voltage Power Supplies for Home Television Receivers," recommended by the AIEE Committee on Communication and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17-21, 1949. Not scheduled for publication in AIEE *Transactions*.

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transformerless sets. Half-wave doubling and tripling circuits are employed. The $B+$ power for the radio-frequency, intermediate-frequency, video, and audio amplifiers is provided through the selenium half-wave rectifier. The power for the audio amplifiers is taken from the first 100-microfarad capacitor. An additional *LC* filter is used to provide the nominal 120 volts for the radio-frequency, intermediate-frequency, and video amplifier circuits.

A negative source of approximately 140 volts is developed by means of section *1* of the twin rectifier *25Z5*. This negative voltage is used not only as bias source, but also as the cathode return for the sweep amplifier tubes.

The selenium rectifier, in conjunction with section *2* of the *25Z5* rectifier and the first 100-microfarad filter capacitor, constitutes a half-wave voltage doubling circuit to develop 250 volts across the 40-microfarad capacitors shown. The 250 volts thus developed is usually employed to provide plate power for the radio-frequency high-voltage power supply. (This supply is discussed in a later section of this article.)

When the "hot" side of the input line is positive with respect to the chassis, a maximum of approximately 163 volts plus 250 volts, or more than 400 volts positive with respect to ground, is available at the plate of the *6X5* rectifier. This acts as a half-wave voltage tripler, developing +400 volts at the 30-microfarad capacitor. This 400 volts is used in the plate circuit of the amplifiers that drive the cathode-ray tube deflection plates. The 400 volts thus generated, together with the −140 volts previously discussed, gives a source of over 500 volts for sweep purposes.

The $B+$ and bias power supplies available in virtually all commercial television sets designed for home use are variations to a smaller or greater degree of the circuits shown in Figures 1 and 2.

HIGH-VOLTAGE POWER SUPPLIES

The high-voltage power supply in a television set is required to accelerate the beam of electrons to a high enough velocity so that, when the beam strikes the phosphor on the inside of the front face of the cathode-ray tube, light of sufficient intensity for satisfactory viewing is produced. In order to improve picture quality in terms of greater brightness, higher voltages must be resorted to. To obtain more light at a given voltage, the current can be increased somewhat. However, because of the mutual repulsion between the electrons in the beam, the current in the beam is definitely limited; otherwise, objectionable defocusing or large beam size is obtained. For proper picture definition, as narrow a beam as is consistent with sufficient intensity is required.

At the present state of electron gun art, a thin line, on a cathode-ray tube screen in a home television receiver, cannot be obtained with currents much in excess of 400 microamperes. Because of the low current requirements, high-voltage power supplies other than straightforward rectified 60 cycle are available, and these are employed in home television sets.

Although 60-cycle high-voltage power supplies were common in television sets built before 1945, since then the high-voltage power supplies have been designed to be less expensive, more compact, and safer in operation than rectified 60-cycle units. Three types have been developed, the flyback, the radio-frequency, and the pulsed power supply.

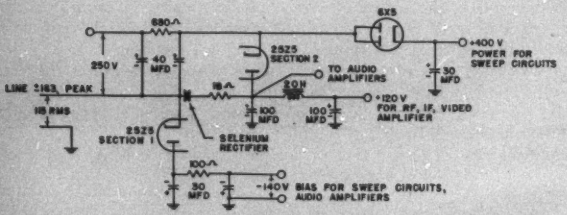

Figure 2. Circuits for providing B+ and bias voltages, in typical electrostatic deflection 7-inch television set

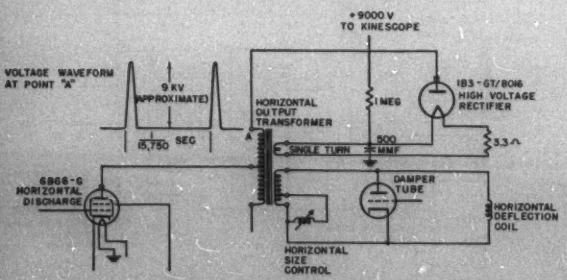

Figure 3. Fly-back high-voltage power supply circuit for 10 kv

RECTIFIED 60-CYCLE SUPPLY

The advantage of the straightforward rectified 60-cycle power supply is primarily great reliability and simplicity of design. Regulation and ripple in a moderately priced unit are fair, and can be made as good as desired by proper transformer, rectifier, and filter design.

The most serious disadvantage is the bulk of a rectified 60-cycle power supply. The secondary winding of the 60-cycle transformer cannot be wound in production with wire much smaller than number 41 gauge. This size of wire is capable of handling considerably more than the one-half milliampere required, previously discussed. Thus, the transformer is inherently a bulky and heavy device, with correspondingly high cost. The necessary filter capacitors are also bulky and expensive.

An additional disadvantage is the danger

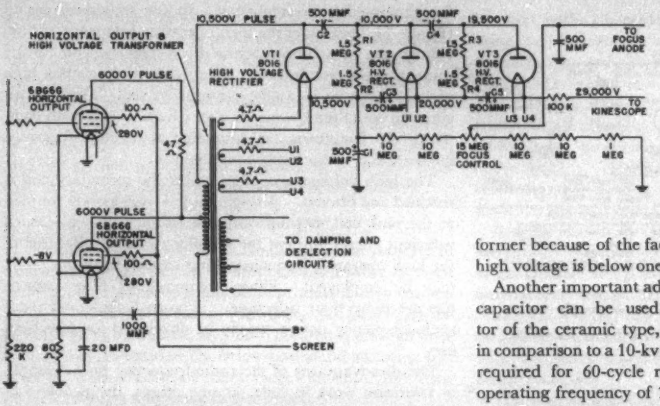

Figure 4. Fly-back high-voltage power supply circuit for 29 kv, as used in some projection television sets

due to the relatively large amount of energy stored in the filter capacitors. Thus, a typical 10-kv supply will employ two capacitors of 0.05 microfarad each. These can produce extremely unpleasant, even though not fatal, shocks, if touched when they are fully charged.

Rectified 60-cycle high-voltage power supplies are seldom used in home television sets today. They are employed in some commercial and military applications where reliability is of importance, and cost and size considerations are secondary.

THE FLY-BACK SUPPLY

The most commonly used type of high-voltage power supply is the fly-back power supply, employed in magnetic deflection television sets. This type of power supply utilizes the surge of high voltage generated across the horizontal deflection transformer when the current in the deflection coil is suddenly reversed to bring the scanning spot rapidly from one side of the cathode-ray tube to the other. With a primary inductance in the deflection transformer of approximately 0.4 henry, and a peak-to-peak current of approximately 0.12 ampere, 6,000 volts are readily developed. This peak voltage can be applied to a rectifier to charge up a capacitor. The basic elements of the fly-back circuit are shown in Figure 3.

The advantages of the fly-back power supply are related primarily to low cost. Since a deflection transformer is required for the cathode-ray tube in a magnetic deflection set, there is no additional high-voltage transformer cost when a fly-back power supply is used. Extra turns on the deflection transformer step up the afore-mentioned 6 kv to 9 or 10 kv, the voltage required for proper picture brightness on a 10-inch kinescope. One turn of polyethylene-insulated wire, coupled loosely to the deflection transformer core, is needed to energize the filament of the rectifier. The total cost added to the deflection transformer because of the fact that it is being used to develop high voltage is below one dollar.

Another important advantage is that a very low cost filter capacitor can be used. A 500-micromicrofarad capacitor of the ceramic type, rated at 10 kv, is extremely cheap in comparison to a 10-kv 0.05 microfarad paper capacitor, as required for 60-cycle rectification. Because of the high operating frequency of 15.75 kc, the ripple is less than one per cent with a beam current of 300 microamperes at 10 kv. A final advantage of this type of power supply is safety, because of the small amount of stored energy in the low value of filter capacitance.

The disadvantages of the fly-back power supply are not serious for home television set use, although they must be taken into consideration if a high quality picture is desired. The fly-back power supply has inherently poor regulation. The internal resistance is basically of the order of ten megohms. Thus, if the picture brightness should change so as to result in a beam intensity increase from 100 to 300 microamperes, the beam voltage would drop from 9,000 to 7,000 volts, or a change of approximately 25 per cent. This would result in beam defocusing and an increase of picture size.

A serious disadvantage accrues in fly-back supplies when very high voltages are required. Because of the pulsed nature of the high peak voltage, a rather complicated voltage multiplying circuit is needed, as shown in Figure 4. The operation of this circuit is somewhat as follows.

On the first high-voltage pulse, capacitor *C1* is charged through rectifier *VT1*. During the quiescent period between pulses, *C1* charges up capacitor *C2* to the polarity shown, through resistors *R1* and *R2*. When the next high-voltage pulse comes, the voltage previously generated across

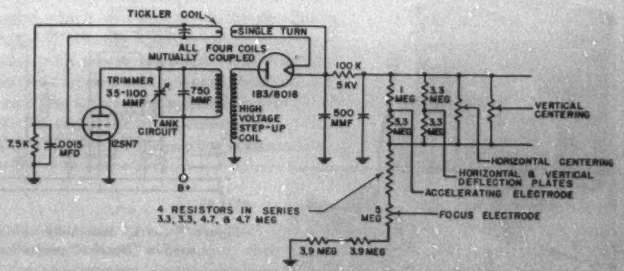

Figure 5. Circuit of radio-frequency power supply for voltages up to 10 kv

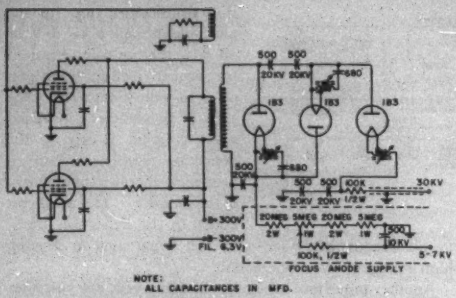

Figure 6. Circuit of radio-frequency power supply for 30 kv

Note the resonant filaments' energizing circuits, driven by plate-cathode capacitance coupling

C2 adds to the pulse voltage to charge up capacitor *C3*, as shown, through rectifier *VT2*. During the next quiescent period, capacitor *C3* cannot discharge through *VT2*, but can charge up capacitor *C4* to the polarity shown, through resistors *R3* and *R4*. On the next pulse, capacitor *C5* is charged through capacitors *C2* and *C4* and rectifier *VT3*.

This voltage tripler is capable of producing 29,000 volts for projection tubes. The volume occupied by a voltage tripler of this type is greater than the volume occupied by a 60-cycle rectifier of the same rating. However, the overall cost is less than that of the 60-cycle unit.

RADIO-FREQUENCY POWER SUPPLIES

In television sets, radio-frequency supplies are employed where magnetic deflection circuits are not available, such as in electrostatic deflection tube sets, or where performance better than that obtainable with a fly-back power supply is required. The theory of the radio-frequency power supply has been discussed by Schade.[1] Basically, the operation is as follows (Figure 5).

A sine-wave oscillation of the order of 100 kc in frequency is developed in an ordinary radio-frequency oscillator circuit. The tank coil of the oscillator circuit is coupled to a step-up transformer that increases the voltage amplitude of the generated radio-frequency. In the secondary circuit (Figure 5), because of the high operating frequency, a high voltage can be achieved across the voltage step-up coil by resonating the circuit, rather than by depending upon high ratio of turns, as in a 60-cycle transformer. Thus, an air core coil with high Q can give a very high voltage with comparatively few turns (as compared to a 60-cycle transformer), and without any coupling iron.

The high voltage generated across the secondary coil is rectified and filtered. A single turn of wire, loosely coupled to the tank coil, step-up coil, and tickler coil, will absorb sufficient energy to heat the rectifier cathode. Because of the high operating frequency, filter capacitors of low value may be employed; 500-micromicrofarad filter capacitors are more than adequate. Figure 5 shows a typical radio-frequency power supply as developed for television use.

The disadvantages of the radio-frequency power supply in television work include, among others, the problem of radio-frequency interference in the picture. Since a television video signal includes frequencies from 30 cycles to several megacycles, an interfering signal from a radio-frequency supply can show up in the picture. As the video amplifying circuits are sensitive to milliwatts or microwatts of power, careful shielding is required of the radio-frequency power supply circuits to prevent radio-frequency interference. At radio frequencies, corona is a more serious problem than at 60 cycles. In order to achieve the high Q secondary coil of Figure 5, thin wire must be used, and air insulation is mandatory. The thin wire represents a source of corona, and under humid conditions, the corona generation is serious.

The radio-frequency power supply has poor regulation, due to impedance matching problems.[1] Where cost is not an important factor, automatic regulating circuits can be incorporated into the radio-frequency power supply to provide excellent performance. A final problem in power supplies of this type is that of tuning. Each radio-frequency power supply must be tuned separately. When coils are replaced, retuning is necessary.

In radio-frequency power supplies for 15 kv or above, where voltage multiplying circuits are used, it is impractical to operate all filaments by direct coupling to the oscil-

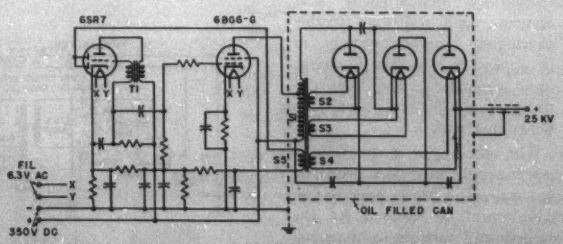

Figure 7 (left). Extremely compact, regulated 25-kv pulse power supply used in "Norelco" projection television system; the can is oil-filled

Figure 8 (above). Circuit of pulse power supply illustrated in Figure 7

lating circuit coil. Such multifilament construction would complicate tuning, and introduce excessive stray capacitance. Instead, advantage is taken of the capacitance between plate and anode of the rectifier tubes to excite a resonant circuit tied across the filament of each tube, as shown in Figure 6. Even though the anode–cathode capacitance is only of the order of five micromicrofarads, the high inverse voltages are sufficient to drive the resonant circuit hard enough to heat the filaments properly.

PULSED POWER SUPPLIES

The pulsed power supply is similar in some respects to the fly-back power supply, in that current flowing through an inductance is suddenly cut off to produce a high voltage across the inductance coil. However, the pulsed power supply utilizes a separate saw-tooth oscillator, and operates at a frequency considerably below horizontal scanning frequency. This produces a much more efficient design than is available from a fly-back power supply.

Siezen and Kerkhof[2] have described a pulsed power supply operating at 1 kc, delivering 25 kv, regulated, for television purposes. The over-all size of this unit is seven inches by seven inches by four inches, as shown in Figure 7. Because of the low frequency of operation, operation under oil is feasible without loss of Q. At 1 kc, the frequency is still so much greater than 60 cycles that the filter capacitors are small enough to represent a nonhazardous amount of stored energy.

Figure 8 is a diagram of the complete pulsed power supply employed in the North American Philips Company Protelgram system. The triode section of the *6SR7*, in conjunction with *T1*, constitutes a blocking oscillator to develop a 1-kc saw-tooth wave. This saw-tooth wave is applied to the grid of the *6BG6G* pentode amplifier. In the plate of this tube is an inductance *S1*. When the sawtooth is building up, current builds up through *S1*. When the sawtooth takes its sharp drop, the current through *S1* is cut off suddenly, producing a high peak voltage at the plate of the *6BG6G*. This voltage is stepped up and subsequently rectified and tripled, by means of the three rectifiers and the three capacitors shown inside the dotted section.

Because the high-voltage wave form generated is a moderately damped sinusoidal oscillation, instead of the single positive sharp pulse of Figure 3, a straightforward Greinacher[3] voltage tripler circuit is possible, resulting in considerably fewer capacitors than in the fly-back tripler; no leakage resistors are needed. (This is also the case for radio-frequency power supplies employing voltage multiplying circuits.)

The advantages of the pulsed power supply are compactness, ease of regulation, lack of radio-frequency interference, and safety. Disadvantages are comparative costliness of the complete unit, due to the extra tubes and coils required. Despite the costliness, this power supply is used extensively by projection television set manufacturers.

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Equipment for Instrument Calibration

EVERETT A. GILBERT

Three types of calibration equipments have been developed which will find ready application as complete self-contained multiranged laboratory standards with power supplies. The standardized output currents and voltages obtained from these equipments can be applied to laboratory instruments and to the production testing of small numbers of diverse measuring instruments.

THE USE of increasing numbers of electric measuring instruments in industry, research laboratories, and the various military services has created a need for a method of convenient and accurate instrument calibration in addition to periodic service checking. The three instrument calibration equipments described in the following paragraphs were designed to calibrate all types of measuring instruments now in use and to anticipate future requirements. As three self-contained units, they supplant the assortment of various range instruments, standard resistors, decade boxes, and variable-frequency power supplies that have been previously required to calibrate even the most common types of electric instruments.

Since electric instruments are both the tools of modern research and the indicators of most electric equipment operation, their application is so wide and varied that many problems arise in the design of a single set of equipment to calibrate all types. For example, in d-c measuring

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types it is not uncommon for self-contained instruments, galvanometers, and chopper amplifiers to have full-scale voltage ranges from one microvolt to 1,000 volts, or full-scale current ranges from one microampere to 100 amperes.

A-c measuring instruments may have full-scale ranges from ten microvolts to 1,000 volts or 100 microamperes to 100 amperes, with many special instruments exceeding these ranges. The rated frequency of common a-c instruments usually ranges between five cycles per second and 60 megacycles per second, whereas the frequencies used in power transmission range only from 50 to 1,600 cycles per second. The common instruments for power application are of the iron vane or electrodynamic type and are usually frequency sensitive, thus requiring that the output frequency of the calibration equipment be readily adjustable to the rated frequency.

Calibration equipment in general must be of a higher order of accuracy than the instruments to be calibrated. An acceptable ratio is about five to one. If the maximum permitted deviation from true value for an instrument being tested is two per cent of full scale, the maximum deviation from true value of the calibration equipment on any range would be about one-half of one per cent of full scale or better. Likewise, instruments accurate to one-half of one per cent require calibration equipment with a maximum deviation from true value of one-tenth of one per cent.

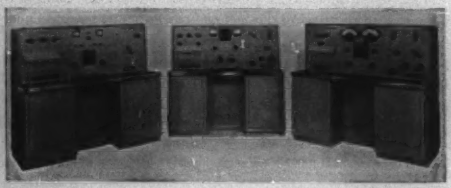

Figure 1. Self-contained equipments for instrument calibration

The three instrument calibration equipments shown in Figure 1 were designed to meet the foregoing requirements. The unit at the left is a self-contained secondary standard for calibrating d-c instruments. This unit will calibrate most common d-c instruments to one-half of one per cent. The center unit is a d-c dual potentiometer standards equipment. The accuracy on all ranges of this unit is one-tenth of one per cent of the reading. The use of calibration cards results in an even higher order of accuracy. The unit at the right in Figure 1 is a standards equipment for use in the calibration of a-c instruments. The accuracy of this equipment is one-half of one per cent.

The cabinets for the three units are of sheet steel finished in gray wrinkle enamel and are 61 inches long, 32 inches wide, and 59 inches high. Weight of each unit is approximately 900 pounds. A linoleum-covered counter is provided for a convenient work table with leg space underneath the center portion, so that measurements can be made while sitting. Operator protection on all ranges above 150 volts is provided by means of a removable transparent plastic hood which covers both the instrument under test and the voltage output terminals. All entrances to high-voltage compartments are equipped with interlock switches, which cut off the input power source when the doors are opened. Internal heaters prevent moisture condensation in humid climates.

All three units are designed to operate from an a-c power source of 110–120 volts having a frequency within the range of 50 to 1,600 cycles per second.

D-C INSTRUMENT CALIBRATION EQUIPMENT

All the circuits used in the d-c instrument calibration equipment are conventional and are conveniently set up by means of selector switches. The circuits are of two non-connected groups—one group for current calibration and the other for voltage calibration. This arrangement was selected so as to allow a-c wattmeters of the electrodynamic type to be calibrated by the d-c method.

The current circuits used consist basically of a storage battery, an adjustable series resistor, and a special Weston Model *273* ammeter. A 100-ampere 100-millivolt shunt in series with the output leads allows standard voltages down to one microvolt to be obtained. The selector switches change the battery voltage, the adjustable resistors, and instrument shunt to cover ranges from 7.5 milliamperes to 150 amperes.

The basic voltage circuit for d-c voltmeter calibration consists of fine and coarse variac controls, an electronic rectifier, voltage dividing networks, and a multirange standard voltmeter. The voltage ranges covered are from 0.075 to 1,500 volts full scale. A decade box and series resistor are used to standardize small currents in the range of 0.75 microampere to three milliamperes.

For an over-all calibration accuracy of one-half of one per cent, Weston fan-type moving-coil d-c instruments are used. For applications calling for one-tenth of one per cent accuracy, the circuit positions of the standard ammeter and standard voltmeter are taken by two Leeds and Northrup type *K* Brooks potentiometers with a precision Leeds and Northrop shunt box and a volt box.

A-C INSTRUMENT CALIBRATION EQUIPMENT

In the a-c instrument calibration equipment, multirange instrument current transformers and potential transformers provide the necessary standard voltages and currents. These transformers are energized by means of a variable-frequency electronic power oscillator. The output frequency range of the power oscillator is 50 to 1,600 cycles. The higher frequencies are necessary to calibrate instruments used by the aircraft industry. The potential and current transformers have been designed to accurately cover this wide frequency range.

The voltage and current output of a-c calibration equipment must be free of harmonic distortion. For the a-c calibration equipment shown above, a conventional Wein bridge oscillator circuit was designed with component values adjusted for minimum distortion. This oscillator drives a power amplifier in which is incorporated a large amount of negative feedback. The power amplifier in turn energizes the current or potential transformer.

Study of Primary Networks at Pittsburgh

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THE 4-KV PRIMARY NETWORK type of distribution system has been used successfully in the Pittsburgh area since 1931, when the Verona-Oakmont network was placed in service. A new 4-kv primary network installation for the Squirrel Hill area has been installed utilizing the modern equipment that is now offered by manufacturers.

The Verona-Oakmont network has three 1,500-kva transformer units supplying an area of about 4.7 square miles. Each network unit is equipped with a 4-kv transformer oil circuit breaker with network relaying, three single-phase induction bus regulators, and automatic 4-kv oil circuit breakers on the tie mains. These mains are 1/0 open wire lines with cable connections to the breaker cubicles. The 22-kv single radial connections to the network units are made with open wire extensions and underground cable to a 3-position switch on the network transformers. For the purpose of obtaining experience with various types of installation, one unit was installed underground, one in a small building, and one outdoors.

The peak load on this network has increased from about 1,300 kva in 1932 to almost 4,000 kva in 1947. A study is being made relative to the addition of a fourth unit. The operating experience with the network has been quite satisfactory. Flexibility in operation and ease of obtaining outages for maintenance and testing have been proved. Week-end outages and the planning of equipment outages long in advance are unnecessary. It has been difficult to maintain the unit that is installed underground and this type of installation is considered undesirable.

During 18 years of operation, there have been no interruptions to load due to inherent conditions of the network. There have been total network outages, but they were due to system conditions which would have resulted in distribution load interruptions if the circuits had been radial. Faults on station equipment have not resulted in any outage to load. Distribution circuit faults have been cleared in all cases without outage to other than the faulted circuit.

When originally installed, the Verona-Oakmont network operated without compensation in the regulating circuit. Circulating currents flowed which caused repeated opening of the bank breaker at one of the units by operation of the network relay. Inverse reactive compensation was added to correct this condition. Resistance compensation was added later, as loads increased, to provide nearly constant bus voltage. Tests show a favorable balance of load, regulated voltage, and power factor of load current with compensator settings of R-13 and X-24 and less favorable results for other compensator settings.

A second network has been installed. The new features in this, the Squirrel Hill network, as compared with the Verona-Oakmont network include the following items:

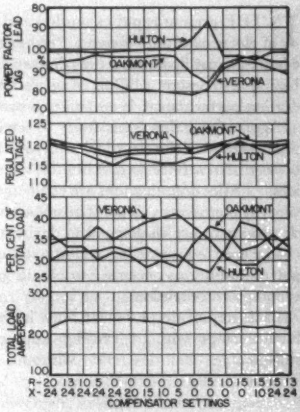

Figure 1. Effect of changes in compensator settings on load division, regulated voltage, and power factor of load current

1. Larger and more economical size unit, that is, a 3,750-kva unit instead of a 1,500-kva unit.

2. Regulation by means of tap changing under load in place of induction regulators (inverse reactive compensation, however, is provided for both systems).

3. Air circuit breakers instead of oil breakers for 4-kv switching.

4. Elimination of 4-kv potheads in circuit breaker cubicles by using rubber-insulated cable for connections to 4-kv circuits.

5. Factory-built unit-type equipment.

6. Alley locations for two out of three unit installations. Ground space at the third site accommodates the mobile unit substation.

Advantages of the 4-kv primary network type of distribution are covered by the following summary:

1. Test results and operating experience confirm the effectiveness of inverse reactive compensation to provide satisfactory division of load between network units, to improve stability, and to reduce circulating currents.

2. An 18-year performance record for 1931–1948 of the Verona-Oakmont 4-kva primary network system provides convincing evidence of a high degree of service reliability.

3. The primary network is attractive from a system cost point of view, provided conditions in the area to be served include reasonably uniform load density, substantial overload relief requirements, and the need for a high degree of service reliability.

4. The interconnected mains between network substations, which provide 2-way service to all loads, permit maintenance without prearranged switching or outage to any customers. Only extended unit outages require the use of the mobile unit substation.

5. The Squirrel Hill network will be equipped with modern network units of the factory-built package type. These units will be cable connected and completely metal-clad, and have been selected with consideration for economical size.

Digest of paper 49-179, "Primary Networks on the Duquesne Light Company System," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Planned Development of a Power System

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IN THE present rapid expansion and future development of electrical utility systems, "economic workability," or economic justification, is the primary criterion of good or bad system design. "Operating workability," that is, operating performance, is no longer a problem.

Aggressive action is necessary to retain the present favorable position of the electrical utility industry in the relation of cost of its service to cost of other commodities and services. Sales organizations are challenged to provide a continually increasing volume of business and planners of system development are challenged to devise a set of patterns that can be used to provide in a continuous and harmonious manner the additions necessary to obtain greater capacity and economy in operation.

Each step of development must leave the door open for further steps without causing untimely obsolescence of still-useable facilities and without overbuilding. The various component parts of the system must be correlated with each other to avoid providing a higher relative degree of reliability in any one link than can be justified by the rest of the chain. Service must be of the quality of voltage level and continuity to promote uses of electricity.

These general thoughts are used in the development of the Pennsylvania Power and Light Company. This system covers an area of 9,500 square miles in central eastern Pennsylvania with a widely dispersed population and relatively few large communities. The area is now served by a network of over 1,200 miles of 66-kv lines. Peak load is over 650,000 kw and the system is interconnected with neighboring systems. Lightning and sleet are often frequent and severe in many parts of the territory.

The patterns of development utilize four standard system voltages. Careful reappraisal shows these are adequate and economical for indefinite expansion with greater loads.

Expansion of carrying capacity of lines follows the general pattern of "making the receiving end today into the sending end tomorrow," illustrated for a 12-kv situation in Figure 1. This pattern continually reduces the distance power is transmitted at each voltage, by addition of higher-voltage sources. It is important to recognize the proper time to introduce a new source instead of adding lower-voltage circuits that will not be fully useable after the new source is provided.

Fitting in with this pattern for expansion of line capacity and supplying to customers directly from all standard voltages except 220 kv, voltage is controlled by raising or lowering the entire system level to fit the load by means of generating stations, synchronous condensers, switched capacitors on 12- and 4-kv feeders, and load ratio control at points of step down from 220 kv. Substation layouts recognize the two independent basic functions of transformation and switching and provide the minimum of equipment to perform each. In the expansion of generating capacity, the aim is selection of optimum conditions for the prime function of the efficient production of electric power, economically co-ordinated with the load characteristics of the interconnected systems and independent of strictly local requirements of voltage control and area protection.

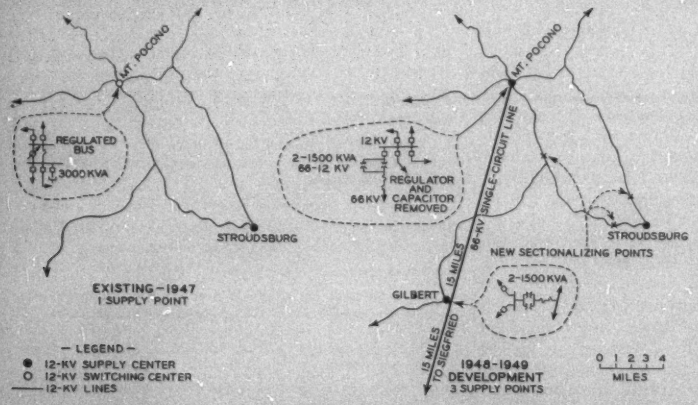

Figure 1. Application of pattern for increasing capacity of 12-kv system in Pocono-Hawley region

Continuity of service must be co-ordinated with the cost of providing it and the revenue received. The degree of continuity of service does and will continue to follow closely the population and load densities. The patterns established contribute to planned improvement of continuity, making full use of operating workability to attain correlation of reliability of all system components.

Digest of paper 49-171, "Planned Development of a Power System," recommended by the AIEE System Engineering Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Not scheduled for publication in AIEE *Transactions*.

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Quality Control as a Management Method

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As a consideration of quality control as a management method, rather than a discussion of the technical approaches to the subject, this article points out that improved product quality, reduced manufacturing losses and costs, and better product designs are among the benefits which management can gain from a modern, coordinated quality control program.

ENGINEERS, scientists, and statisticians, until recently, have been the groups chiefly interested in activity called "quality control." These technologists have been primarily interested in the technical methods which have become associated with the subject. They have applied these same methods to a number of factory quality problems.

Excellent results in improving quality and reducing costs are now being reported from these applications. These reports have generated growing interest by other members of management in the potentialities of "quality control."

What, these other management people are asking, is meant by the term, "quality control?" Is there anything really new about it? What are the quality control activities? What is the proper organization for quality control? How much does the program cost, and what benefits can result from it?

Is quality control good only for mass production, or may it be useful in a job shop as well? What does quality control mean to the foreman, to the design engineer, to the salesman? How is quality control introduced to a factory?

Discussion of questions such as these is the objective of this article. It will endeavor to present quality control as a management method; the article will not be primarily concerned with technical approaches, about which there is a growing wealth of literature.

THE GOAL OF PRODUCT QUALITY

Management's product quality goal may be simply stated. It is to manufacture a product into which quality is built and maintained at the most economical costs which yield full customer satisfaction.

Such a goal is not a new one. Industrial history records a wide variety of plans developed by management to meet its product quality problems. Operator education, foreman training, inspection in the sense of sorting the "bad" pieces from the "good," preventive maintenance are a few of the more recent instances of such programs. While the term, quality control, was not usually applied to these plans, the control of quality was their major objective.

The one certainty about quality problems is that their content will change with the times. Results from these earlier versions of quality control are, in many plants, no longer adequate to meet management's quality objective.

The quality of products placed in the hands of customers generally has been good. The price manufacturers have paid to support this quality grade, however, has been excessive.

Neither this quality nor this cost picture is satisfactory. The present era of increasingly aggressive competition will not permit a plant to have a quality record that is only "relatively" good. Its record must be very good. With cost reduction a primary aim of management, this quality improvement cannot be accomplished simply by means of expenditures that will boost the already high quality costs. The job must be done in many instances at less, not more, cost. The quality control job facing management today requires, therefore, a double-barrelled solution: A considerable improvement must be effected in quality of those products which require such improvement; at the same time, substantial reduction must be made in the costs for supporting and improving the quality of these products.

Why have these quality problems becomes so serious today? What are the industrial changes that have caused them to arise? Two developments of the past decade have impelled management to search for improvements in its older quality control methods.

The first development is a technical one. Customers' quality requirements have become far more precise than ever before. The relay that was acceptable in 1939 must perform with much greater accuracy today if it is to serve certain portions of the modern market. The machined part that once was checked with a pocket scale must now be measured with a pair of micrometers or even an air gauge.

Material specifications have become more rigid. Tooling has become a more critical factor. "Intangibles" like dust in the air and humidity have become both extremely tangible quality problems and the objective of elaborate safeguards. Many prewar methods for producing and measuring quality no longer meet present standards.

The second development is a matter of human relations. Plant expansion and war turnover wrought many changes in once stable work groups. Green operators are still the rule of the day in many shops. The road back to the pride of workmanship, that is the core of any successful quality control program, is one that is neither found automatically nor travelled overnight.

Most product quality responsibilities were once the exclusive province of the foreman. Some of these responsibilities are now widely scattered among many factory specialists. Poor quality of a part may be due to unsatisfactory specifications written by the design engineer, to faulty procurement by the purchasing agent, to inadequate

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testing by the laboratory technicians, to unsuitable processing equipment installed by methods engineering. With modern organizational practice, quality control may no longer be exclusively pinned down to the team of the factory foreman and the old 100 per cent "sort the bad from the good" inspection department.

Management's objective of better quality at lower cost is, therefore, complicated by the double-barrelled problem of demand for greater product precision on the one hand and by the issues rising from more involved human relations on the other hand. Is management's quality objective attainable under present industrial conditions?

Practical experience has shown several instances where just such an objective has been obtained by management with a practical, common sense program of modern quality control. To illustrate such a program, the experience of the "X Company" will be cited. X Company is taken to be representative of a typical present-day industrial concern and its experience with quality control will be brought out by the discussion of several questions.

I. WHAT IS THE DEFINITION FOR QUALITY CONTROL?

Suppose that management of the X Company decides to establish a quality control program. It will want first to outline the scope and responsibilities of the new activity. How is quality control to be defined?

Management may immediately encounter a difficult problem. During the past several years, the term "quality control" has been applied to most of the proposals that have been advanced for improving product quality and for reducing the cost of its maintenance. The activity has come to have almost as many definitions as there have been systems proposed for its use.

Is quality control to refer to a series of sampling inspection methods? Is it to designate the troubleshooting of factory reject problems? Is the activity to be made synonymous with industrial statistics?

These definitions refer to individual methods for controlling quality. X Company management rejects them as being too restrictive.

It conceives of quality control as the over-all, factory-wide program for attaining management's quality goal. Such a broad program includes many of these individual methods, to be sure, but its primary function is the organization and administration of these several methods.

X Company management wants its definition for quality control to mirror this administrative point of view. It accepts one such as the following:

> Quality control is the X Company system for co-ordinating the quality maintenance and quality improvement efforts of the various groups in the organization so as to enable production at the most economical levels which yield full customer satisfaction.

Maintenance of tools so that they will produce satisfactory parts is believed by X Company to be a quality control activity. So is the periodic check of thread gauges, the analysis by draftsmen of tolerance-buildups, the use of machine floor inspectors, the determination of the accuracy of machine tools, the use of sampling inspection plans.

A popular, slogan-like version of X Company's definition might be used. It states that, "Quality control means co-ordinating the job of making the product right the first time at the best cost, which enables full customer satisfaction."

II. WHAT IS NEW ABOUT QUALITY CONTROL?

Is there anything genuinely new about modern quality control as conceived by the X Company? Does it merely represent a new label applied to the reshuffling of well-known techniques?

Modern quality control differs from earlier versions of the activity in two important respects.

First, modern quality control integrates the usually unco-ordinated approaches to control of quality into an over-all program for a factory. Quality control activities have, like Topsy, "just growed" during the past decade. The value of an over-all, co-ordinated plan in place of sprawling, disjointed activities is well known in factory administration. This organization of effort is extremely important, if not a single new quality control method is added to the factory's program. It is even more important if new techniques like the control chart are employed.

The second respect in which modern quality control is different is just this: it may use in its programs a number of new techniques for dealing with, measuring, and thinking about the increased emphasis upon precision. Statistics is one of the most useful of these methods. Modern gauging practice is another.

III. WHAT IS A QUALITY CONTROL PROGRAM?

Now that the hypothetical X Company has agreed upon its philosophy of quality control, its next step is the development of actual quality control activities.

"Our long-range objective is a complete quality control program for our shops," states X Company management. "Let's start by developing such a program for one of our products—an electric snapper."

What is this complete quality control program? What methods are used in the program? Are its activities confined to inspection work? Are the production and engineering groups involved? Answers here depend upon the determination of still more basic questions: What affects the quality of the electric snapper? Where is it affected? During design? During machining? In final assembly? How is the quality affected? Who affects it?

Those factors which may have important effects on snapper quality must be controlled if management is to attain its quality goal for the product. It is the consolidation into an over-all program of various techniques for this control which constitutes a complete quality control program.

The X Company electric snapper passes through many hands and processes before it is finally received by the customer. It is merchandised by a marketing group which broadly establishes the product specifications. It is designed by an engineering group which turns these requirements into actual factory standards.

Its materials are procured by a purchasing group which has an important effect in determining the quality of these materials. The jigs, tools, and fixtures for its production may be developed by a methods group. Parts are manufactured and assembled by a production group.

Materials and life-test performance may be approved by a

laboratory group. Conformance to standards is checked by mechanical inspection and electric test groups. The container in which the snapper will be transported may be developed by a packaging group. The product is placed in its container by a shipping group.

Quality of the electric snapper may be affected at several of these stages in the production process. It may be affected by human beings—operator carelessness, inadequate supervision, poor design, unsound specifications by the sales manager.

It may be affected by mechanical factors—inaccurate machine tools, decrepit jigs and fixtures. It may be affected by natural causes—dust in the air which coats over the snapper contacts, excessive humidity which causes chemical action on the parts.

So a complete quality control program starts with the design of the electric snapper and does not end until the snapper is placed in the hands of a customer who is satisfied with it. The activities to support this program fall into four natural classifications, which are

1. The control of new designs and new products.
2. The control of incoming purchased parts and materials.
3. The control of parts from machines, processes, and assembly lines.
4. The conducting of special tests of factory and processing problems.

These four quality control activities gear directly into four major stages of producing the electric snapper and each of them is supported by definite routines. These routines are approved by X Company management in accordance with a definite plan. They are part of factory practice just as are production control or cost control routines. The existence of these routines and their integration into an over-all system is the very heart of electric snapper quality control.

There is a definite approach at the core of these quality control routines. It is that of preventing rather than correcting poor quality after an article has been manufactured.

Another major feature of the activities is their positive effect in building up operator responsibility for and interest in product quality. In the final analysis, it is a pair of human hands which performs the important operations affecting product quality. It is of paramount importance to successful quality control that those hands be guided in a skilled, conscientious, and quality-minded fashion.

IV. IS QUALITY CONTROL GOOD ONLY FOR MASS PRODUCTION?

Suppose that the X Company decides to establish quality control programs for products other than the electric snapper. Will this same framework of activities be applicable to these products? Is it useful for large apparatus as well as small devices, for items built in mass quantities as well as those produced in job lots?

In the company which carries on both design and manufacture, roughly similar steps must be followed for all products. The articles must be designed, materials must be purchased, parts must be produced, these parts must be assembled together. A similar quality problem exists at each of these production stages, no matter what the nature of the product or the quantities in which it is to be built.

In mass production operations, product quality can be effectively controlled by types of parts, since all parts will be the same. However, in job-lot manufacture, the parts differ from job to job, and only the process by which they are produced is common to all types of products.

Therefore, in mass production manufacturing, quality control activities center on the product, while in job-lot manufacturing, it is a matter of controlling the process. So the philosophy, framework, and routines may remain comparable for all products. Individual quality control methods used will vary, however, from product to product.

V. HOW DO STATISTICS RELATE TO MODERN QUALITY CONTROL?

A wide variety of technical methods is available to the X Company for use in its quality control program.

Industrial statistics is currently the most widely heralded of these methods. The statistical approach may be simply summarized: Variation in quality characteristics (inner diameter of bushings, hardness of studs, viscosity of varnish) must be expected among all processed parts, assemblies, and batches. This variation may be studied best by the selection and analysis of small samples of these parts and assemblies.

These sample studies may determine, for a given part or material, the amount of variation that is economically acceptable. They may aid in holding the variations occurring during product manufacture to these economic limits.

Four statistical techniques may be useful to X Company in this work:

1. The *frequency distribution*, which is a tally of the number of times a given quality characteristic occurs within a sample of product. As a picture of the quality represented by the sample, it may show at a glance:

   (*a*). The average quality.
   (*b*). The spread of the quality.
   (*c*). The comparison of the quality with specification requirements.

   The frequency distribution may be used in such instances as the study of the amount of deviation among batches of foundry sand, and the analysis of the variability in the performance of relays at preshipment electrical test.

2. The *control chart*, which is an hour-by-hour or day-by-day graphical comparison of actual product quality characteristics with limits reflecting the ability to produce as shown by past experience on the characteristics. When the graph's curve approaches or exceeds the limits, process change is indicated which may require investigation.

   The control chart is useful in such applications as the maintenance of a continuing check on the quality of articles produced by machine tools and painting equipments.

   The chart also may furnish a valuable record of tool wear or other forms of process shifts.

3. The *sampling tables*, which are a series of schedules for representing, at a given risk, the quality (usually expressed in per cent defective terms) of an entire lot from a sample properly selected from that lot.

   Sampling tables have been useful in some of the more highly publicized quality control jobs. They are of value in replacing expensive 100 per cent sorting, and in the establishment for new products of inspection procedures which strike a balance between quality protection and inspection economy.

4. The *special methods*, which comprise such techniques as correlation, significance tests, and analysis of variance. These methods have been hewn, for industrial quality control use, out of the general body of statistics.

   Special methods are useful in many analyses of engineering designs and process troubles. Will experimental grid *A* have a better effect on electronic tube performance than will experimental grid *B*? Is

hardness of the metal the cause of the breakage of screws being assembled to silicon steel covers? Is furnace temperature a critical factor in causing variations in casting quality, while metal and furnace atmosphere are relatively unimportant?

Several applications of these statistical techniques have developed into full-fledged technical methods. Machine operation accuracy studies are basically a special adaptation of the frequency distribution.

The object of machine operation accuracy studies is to determine the amount of variation that must be normally expected from a machine tool operation under a given set of circumstances. With these machine conditions—tooling, materials, coolant—held constant, a sample of parts is produced. The sample then is examined by means of a frequency distribution analysis.

The conclusions of this analysis may be compared and consolidated with two or three similar studies on the same machine. The final results may be phrased as follows: "Machine 112 has an operation accuracy of $+$, -0.004 inch on a cut-off operation, on *XB5* brass, using as tooling. . . ." With this knowledge, the planning engineer can route metal working jobs to machines best suited for handling them.

VI. ARE STATISTICS THE ONLY QUALITY CONTROL TECHNICAL METHOD?

Statistics are an important technical method. But X Company also will require many other technical methods to support a complete program of the four quality control activities. Here are some examples:

1. Machine tools, processing equipments, jigs and fixtures inevitably will wear under constant use. The resulting loose bearings and worn pins may cause poor quality products. A program of *preventive maintenance* may be an important quality control method, since it enables a regularly scheduled examination of processing facilities before they break down.

2. Production conditions may result in operators "taking all the tolerance" that is permitted by parts drawings. Difficulties may develop in assembling these parts that had not been visualized when the product was on the drafting board. *Tolerance analysis* is a basic quality control method, because it establishes an organized means for determining tolerance buildups while the product is being designed and developed.

3. Parts may be presented for inspection at a time when the inspector does not have proper gauges either available or accessible to him. Examination of the product may be after the tenth operation, when it may be the third operation that is critical and troublesome. *Inspection planning* is a quality control method which establishes the quality and location of the required types of inspection before active production has started. It assures the presence of suitable gauges and fixtures. Hit or miss inspection procedures are thereby minimized.

A host of other quality control technical methods might be noted if space were to permit. Among these methods are those useful for product planning and merchandising, in the establishment of guarantees and specifications, in the trouble-shooting of factory rejects and field complaints, and in the control of tools and gauges.

VII. WHAT IS THE ORGANIZATION FOR QUALITY CONTROL?

With statistics as well as many other methods available for use in the four quality control activities, the importance of adequate organization of the quality control program is obvious. The objective of such an organization for X Company is the establishment and maintenance of these quality control activities.

The wide scope of the quality control organization required becomes apparent from the many phases of the production process affected by these activities. With so many scattered threads to gather together, it is easy to understand why the basic pattern of a successful quality control organization for X Company must be co-ordination of the quality efforts of various plant groups: engineering, manufacturing, sales, inspection. The type of organization indicated by this pattern, in those companies large enough to require it, is a staff group reporting directly to X Company top management and supervised by a quality control head.

This direct line of authority is very important. Without it, the task of co-ordination, control, and the sometimes necessary education of the plant organization would be extremely difficult.

It is not the responsibility of the full-time members of the X Company quality control staff to carry on the various details of the quality control activities. The men best qualified for this work are those in already existing line and functional groups.

It is the quality control staff's responsibility to administer the over-all program for X Company, and to co-ordinate the various product quality projects. One way of accomplishing this co-ordination is through a quality control committee, headed by the chief of the quality control staff, and composed of representatives from each of the important groups which enter into the production cycle.

This approach makes it possible to obtain the benefits of quality control organization with a minimum of full-time expense personnel. X Company, with a fifty million dollar annual output and a large weekly payroll, can operate its quality control organization with one quality control head and two full-time assistants.

The actual details of X Company's quality control organization naturally will differ from that of other companies, due to variations in products, company size, personalities, and product quality history. The program may be assigned to a quality control engineer, a quality manager, a quality control co-ordinator, or a quality appraisal supervisor. Organization of effort may be gained through working committees, or through individual activity. The program may be highly technical and complex in some companies, and extremely simple in others.

The common denominator through all these variations, however, is that co-ordination and control are the basic pattern, and that the four quality control activities are the functions carried on.

VIII. HOW SHOULD A MODERN QUALITY CONTROL PROGRAM BE INTRODUCED?

Without the proper attitudes among X Company's factory personnel even adequate methods and sound organization cannot assure any degree of success to its quality control program. These attitudes must be primarily represented by the very intangible but very important spirit of quality-mindedness extending from top-management right through to the men and women at the bench.

Whatever is new about the quality control program must be sold gradually to the entire plant, so as to obtain its willing acceptance and co-operation. The statement is sometimes made by quality control personnel that their factory organization "is not quality conscious," that it is not "going along with the quality control program." This may be largely an admission by the quality control people that, in introducing their program, they took into proper account only mechanical and not human factors.

Without complete top-management support for quality control, of course, no degree of "selling" can be genuinely effective. The quality control program which receives only lukewarm support from management is foredoomed to a hard road and, very likely, to failure.

Experience seems to indicate that a program such as X Company's should be allowed to develop gradually within the factory. This approach both aids in the selling activity, and also permits tailoring of the general routines to the particular needs of the various shops. It often is found wise to select two or three troublesome quality problems, to obtain successful results by attacking them, and to allow the four quality control activities to grow step-by-step in this fashion.

IX. WHAT BENEFITS MAY BE OBTAINED?

When a quality control program has attained its full growth within a factory, it should be in a position to carry on, for the entire factory organization, all four of the quality control activities. A typical over-all quality control application of this sort is one for the X Company electric snapper previously discussed. A brief résumé of the control on this device, broken down by the four quality control activities which were carried on, is as follows:

1. *Control of new designs and products.*

While the snapper was being designed and planned, special tests and pilot runs located sources of possible manufacturing troubles, and these troubles were eliminated by design and methods changes.

2. *Control of incoming materials.*

Critical dimensions were determined and very careful checks were made of the first lots of parts purchased from vendors. From these, the degree of sampling that could be done was ascertained. Quality contacts with vendors were established and maintained.

3. *Control of parts from machines, processes, and assembly lines.*

Charts were set up on production lines showing how many and what per cent of each part were rejects, so that the factory supervisors could get immediate information as to the presence of quality troubles. Careful attention was paid such factors as preventive maintenance and operator education.

4. *Special studies of factory difficulties.*

If the factory supervision was unable to solve a quality problem, the quality control organization supplied help from the person or persons who were in a position to be helpful, whether engineering, planning, inspection, laboratory, or others.

Compared with the previous model of the snapper on which no such program has been carried out, this over-all quality control aided in obtaining a considerable improvement of product quality, a reduction of 35 per cent in manufacturing losses, and another 35 per cent in inspection and testing costs. The benefits that management may gain from a well co-ordinated, modern quality control program are thoroughly represented in this electric snapper example.

Expressed in more general terms, they are as follows:

1. Improved product quality.
2. Reduced manufacturing losses and costs.
3. Better product designs.
4. Production bottlenecks eliminated.
5. Processing methods improved.
6. A better spirit of quality-mindedness developed in the plant.

ROLE OF MODERN QUALITY CONTROL

From the foregoing discussion, it is readily apparent that modern quality control is not a new cure-all which overnight will gain for management its product quality objectives. Nor is it a substitute for good manufacturing and engineering practices that have been successful over the years.

It is, however, an increasingly necessary management method to be used in conjunction with these time-honored procedures. It is necessary because existing, unco-ordinated, individual quality control techniques are not able to cope with customers' demands for greater precision and the diffusion of quality responsibility; these are the two modern factors which have developed to affect industrial product quality. Modern quality control attacks these two factors directly through improved organization for attaining quality objectives, and more effective use of technical methods.

Properly understood, properly staffed, and above all properly organized, modern quality control is becoming one of the most useful of the tools available to engineers and to industrial management generally in pursuit of their most important objective: to manufacture products into which quality is built and maintained at the most economical costs which yield full customer satisfaction.

Slot Antenna Applications

Both high-speed-aircraft performance and television reception will benefit from a new type of antenna receiver system, according to Norman L. Harvey of Sylvania Electric Products, Inc., who described applications of the slot antenna before the National Electronics Conference which was held in Chicago, September 26-28.

Discussing the antenna's use with television transmitters and receivers, Mr. Harvey stated that it will provide a nondirectional signal pattern resembling a flat doughnut in shape. Suitable for indoor installation, the antenna is essentially a hollow metal tube with a series of narrow slots cut along its length.

Physical dimensions of an antenna applicable to television transmission and reception are: a slot length approximately equal to one-half wave length and a cylinder diameter of approximately one-sixth wave length.

With regard to high-speed aircraft, antenna design has become an important aerodynamic factor, since all projections from the airplane's surface must be minimized. The simple physical shape of the slot antenna offers less wind resistance than previous types. In addition, it provides a signal pattern well adapted to many types of aircraft radio applications.

Comparing Steel and Wood Line Supports

C. A. BOOKER

MOST HIGH-VOLTAGE LINES, in keeping with the trend of thought at the time they were built, have employed steel supporting structures until quite recently. About 15 years ago after an analysis of various high-voltage lines, it was concluded that a properly designed wood line would give superior service from an interruption standpoint.

Cumulative operating records starting in 1921 and involving over 3,600 interruptions to service are segregated by different tower and pole designs in Table I.

Table I. Lightning Interruptions

Line Voltage Kv	Impulse Insulation Positive Kv	Type* Structures	Constructed	Circuit Mile-Years Experience	Lightning Interruptions Per Hundred Circuit Mile Years	Struct. Mile Years	B/W Mile Years
66	285	DC PT ST	1907–1910	4,249	22.3	28.4	31.7
66	490	DC ST	1911–1915	9,014	23.2	28.4	29.8
110	615 / 790	DC ST	1924–1927	5,993	20.6 / 12.8	23.4 / 16.3	25.2 / 16.3
66	390	SC WP XG	1911–1935	5,433	17.4	17.8	24.0
110	680	SC WP XG	1924–1928	1,448	17.4	17.4	17.4
110	860	SC ST	1926–1939	3,150	7.0	7.0	14.8
220	1345	SC ST	1929–1930	4,290	2.75	2.75	5.5
13–66	1500+	SC WP	1937	347	3.6	3.6	3.6
110	2200	SC WP	1939	192	0	0	0

* SC = single circuit; DC = double circuit; PT = pin type; XG = no ground; WP = wood pole; ST = steel tower.

Impulse insulation levels can be increased substantially and at little expense by capitalizing on the insulating characteristics of wood. The exploitation of this useful property has made it possible to obtainsup erior performance on modern wood lines even in the 11 to 22-kv voltage range. Double circuit steel lines suffer simultaneous interruptions to both circuits in about 60 per cent of the lightning disturbances. Such double interruptions are almost unknown on parallel single circuit lines.

Forest and grass fires have been a menace to untreated poles but have not seriously injured creosoted poles on the same right of way. Occasional pole shattering by direct strokes is an annoyance on ungrounded lines. When justified this hazard can be avoided by installing an aerial wire or wires in a position to intercept such strokes and divert them to ground through a system with appropriate insulation and clearances.

The double pole structure with pole crossarm shown in Figure 1 has been developed to obtain the benefits resulting from the use of creosoted wood poles. Such lines have been constructed with impulse insulation in excess of 2,200 kv and work well in territory where ground resistance at individual structures ranges from 5 to over 1,500 ohms with an average of about 390 ohms.

Operating experience indicates that near immunity to lightning can be obtained in this territory when a line incorporates in its design 2,500 to 3,000 kv of impulse insulation, corresponding clearances, and aerial ground wires.

Lines operating at voltages up to 115 kv at least can be designed to meet these requirements without excess cost by taking advantage of the impulse insulating properties of wood.

Table II seems to indicate that properly designed wood transmission lines also offer structural advantages during severe storms because their relative flexibility eases strain under excessive loadings. The table is based on a system having 10,000 towers and 20,000 wood pole structures.

Table II. Structure Failures During Severe Storms of Lines Located on Adequately Cleared Private Rights-of-Way (Damaged and Leaning Structures Not Included)

Date	Storm	Towers	Poles
Dec. 22, 1916	Sleet	6	0
April 2, 1920	Sleet	1	0
Nov. 28, 1921	Sleet	150	3
Nov. 28, 1922	Sleet	0	8
March 11, 1924	Sleet	37	0
Sept. 21, 1938	Hurricane	49	0
Sept. 14, 1944	Hurricane	0	0
Total		243	11

Figure 1. Double pole structure for 110,000 - volt line

Digest of paper 49-173, "Comparative Performance Records—Steel and Wood Transmission Lines," recommended by AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Electrical Analogs of Linear Systems

JAMES P. CORBETT

THIS article is concerned with the problem of representing linear vibrating systems in terms of electric circuits. In standard works, it is shown that a system of linear differential equations with constant coefficients can be reduced to a triangular system by use of a system of multipliers with a constant determinant. The use of a transformation of this type can result in considerable simplification. It is possible to alter the essential type of coupling appearing between loops of the electrical analog circuits by this means. This transformation is particularly valuable since it does not alter the dependent or independent variables, and introduces only rational functions of the original parameters.

If the original system is expressed in terms of operators it appears as an ordinary system of linear algebraic equations. In matrix form, this last transformation is simply a multiplication of this system on the left by a nonsingular matrix of constant determinant, that is, a set of row transformations of the original matrix. A corresponding column transformation of the system can be made: multiplication on the right by a nonsingular matrix of constant determinant.

When the system to be analoged contains a nonlinear element or a simple discontinuity the realization of initial or boundary conditions in the analog must be given careful attention. Even for linear systems there is always the possibility of obtaining simplification in the analog through attention to the realization of a suitable set of initial conditions. In this last connection, the following important fact should be pointed out. In constructing an analog it may be possible to avoid the necessity for exact simulation of an active element by proper attention to the initial conditions under which the analog is operated.

The problem of constructing a suitable electric circuit analog of a linear differential system is closely connected with the problem of constructing a set of two terminal networks of prescribed frequency response. The differential equations are usually given in the form

$$\sum_{j=1}^{n} f_{ij}(D)y_j = 0; \quad (i=1, 2, \ldots, n) \tag{1}$$

with $f_{ij}(D)$ a second-degree polynomial in the operator $D=d/dt$ and with real coefficients. It is always possible to reduce such a system to a triangular system

$$\sum_{j=1}^{n} g_{ij}(D)y_j = 0; \quad (i=1, 2, \ldots, n) \tag{2}$$

where $g_{ij}(D)=0$ for $i>j$, and where the $g_{ij}(D)$ are now in general polynomials of higher degree than two. The last equation which is in the triangular system of equation 2 is of the form

$$g_{nn}(D)y_n = 0 \tag{3}$$

an ordinary differential equation, linear and with constant coefficients. The initial conditions for equation 3 can be deduced from the system equations 1 or 2. The reduction to a triangular system can be accomplished for any ordering of the variables y_j. The original system can therefore be replaced by an equivalent system consisting of n differential equations, each in a single dependent variable, of the form of equation 3. If arrangements are made to control initial conditions in a passive circuit, equations of the form of equation 3 have relatively simple realizations.

Although the foregoing kind of analog is simple from a physical standpoint, it has the property that the coefficients entering into the operator polynomials, $g_{nn}(D)$, are functions of the original coefficients entering into the polynomials $f_{ij}(D)$. For some types of engineering applications this is not a desirable state of affairs and a more faithful analog is required. When a direct circuit representation of the system of equation 1 is attempted, it will usually be found that a relatively large number of active elements is required. Some compromise is therefore indicated and this compromise can be effected by transforming the system of equation 1 in a judicious manner.

The transformation by which the system of equation 2 was obtained from the original system of equation 1 is of the form

$$g_{ij}(D) = \sum_{p=1}^{n} A_{ip}(D)f_{pj}(D) \tag{4}$$

where the elements $A_{ip}(D)$ are polynomials in the operator D with determinant $|A_{ip}(D)|$ constant and different from zero.

A second type of transformation replaces the independent variables y_j by new independent variables, w_j related as follows

$$y_j = \sum_{p=1}^{n} B_{jp}(D)w_p \tag{5}$$

with $B_{jp}(D)$ a polynomial in D and the determinant $|B_{jp}|$ a constant, different from zero.

Using the two foregoing transformations it may be possible to reduce the number of active coupling elements required in the circuit. The necessary compromise is between complexity in the physical realization, and complexity of the transformation.

Finally it is necessary to make transformations of the independent variable, that is, changes of time scale, in order to satisfy the frequency requirements of the basic electric devices employed.

Digest of paper 49-166, "Summary of Transformations Useful in Constructing Analogs of Linear Vibration Problems," recommended by the AIEE Computing Devices Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Primary Network Installations at Boston

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MEMBER AIEE

THE BOSTON EDISON COMPANY has three primary network installations in operation on its system supplying a total load of 43,000 kva. The first primary network installation went into service in 1932 to supply a residential load of approximately 4,500 kva in an area of about 5.3 square miles. This load was supplied with four 1,500-kva transformers rated 13,800-volt primary and 4,330-volt secondary installed in underground vaults 30 feet long by 9½ feet wide by 10 feet high. The transformers, as originally installed, were connected Y-Y with a tertiary-delta winding but they were later rewound for delta-Y operation in order to put the network in phase with the existing radial system which is supplied from delta-Y connected transformers.

In 1941, the second primary network was installed in a predominantly industrial area of approximately 3¼ square miles with a load of about 12,000 kva. This network is supplied by two 4,000-kva and one 3,000-kva primary network units with load ratio control equipment and a fourth bank consisting of two 1,500-kva station-type transformers without load ratio control but with single-phase regulators on the 4-kv mains. These four units are all installed above ground and are connected delta-Y in order to phase with the existing system.

The third network went into service in 1948 in a combined industrial and residential area of approximately four square miles with a load of about 16,000 kva. This load is supplied from four 4,000-kva primary network units, two of which are located together on an existing substation property; the other two are located separately on plots of land purchased for that purpose. One of the plots of land was bought large enough to provide for the installation of two primary network units; the second unit on this plot to be installed in 1949. Wherever possible, the primary network units are located relatively close to existing transmission lines in order to make these extensions short, and by making best possible use of the existing 4-kv circuits very little new 4-kv construction was required.

The operation of the three networks has been exceptionally good. The faults that have occurred on the 14-kv and 4-kv cables of the network system have cleared satisfactorily with a minimum of disturbance.

Studies indicate that the primary network system offers a reliable means of relieving existing over-loaded radial systems where transmission line extensions are relatively short and where existing 4-kv distribution circuits lend themselves readily to the formation of network mains. However, there may be areas in which the double-ended unit-type radial substation will provide a more economical means of furnishing the necessary relief. Therefore, any time load relief is required, careful engineering and economic study is made before any method is adopted.

Digest of paper 49-181, "Primary Network Installations of the Boston Edison Company System," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Not scheduled for publication in AIEE *Transactions*.

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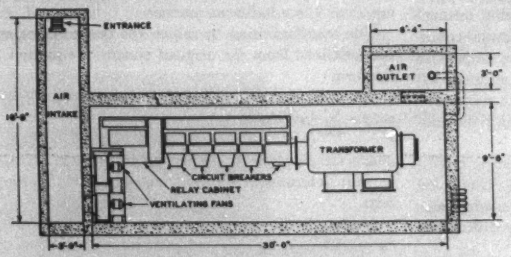
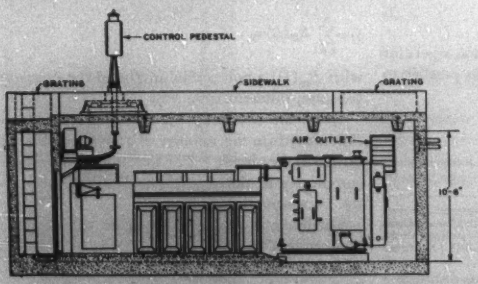
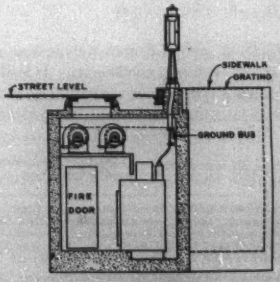


PLAN – PRIMARY NETWORK UNIT NO. 2



ELEVATION – PRIMARY NETWORK UNIT NO. 2



SECTION

Figure 1. 1,500-kva primary network unit in subway vault

Magnetic Ferrites for High-Frequency Uses

FRANK G. BROCKMAN

The outstanding advantage of magnetic ferrites, which are nonmetals, is the low electrical conduction and, therefore, low eddy current losses at the higher frequencies, so that these materials find great usefulness in communications. In this article the author describes the development, the characterictics, and applications of these materials.

THE MATERIAL presented in this article is the outcome of research[1–6] which was conducted in the Eindhoven, Holland, Laboratories of the Philips Company by J. L. Snoek, E. J. W. Verwey, and others. The article concerning magnetic ferrites is divided into the following sections:

1. Background of the research, with special attention to the crystallography of the ferrites.
2. Characteristics of the materials.
3. Applications.
4. A new discovery made in Philips Laboratories, Irvington-on-Hudson, N. Y., regarding these materials.

BACKGROUND OF THE RESEARCH

Ferrites are nonmetals. They are chemical compounds of the general formula $M^{+2}[Fe_2O_4]$, where M^{+2} is a divalent metal and, in this instance, either Cu, Mg, Mn, Ni, Fe^{+2}, or Zn. For instance, the formula for nickel ferrite is $Ni[Fe_2O_4]$. The fact that these compounds possess ferromagnetic properties has been known since the early part of the present century. Indeed, the oldest known ferromagnetic material, magnetite, is a member of the series, being ferrous ferrite, $Fe^{+2}[Fe_2^{+3}O_4]$. Since these materials are chemical compounds, the electrons are bound by valence forces. Because the electrons are bound, the electrical conductivity is small. Low conductivity means low eddy current losses.

It happens that of the list of ferrites given, all are of a particular crystal class. They all have the same crystal structure as the mineral spinel, $MgAl_2O_4$. Crystallographers say then that these ferrites are "spinels." It is known that there are two kinds of spinels, one called "normal" and the other "inverse." In the crystal lattice of any spinel there is chiefly an oxygen lattice which is face centered cubic and the other atoms (Ni and Fe, for instance) are distributed in an orderly fashion throughout the spaces ("interstices") left in this cubic lattice. This orderly arrangement is such that it is possible to imagine the smallest crystallographic unit ("the unit cell") as being broken down into two sets of nonadjoining smaller cubes as in Figure 1. Here are four nonadjoining cubes; another set completes the unit cell.

The arrangement of the ions in one of these subcells is that given in Figure 2. Here the large circles represent the oxygen atoms while the smaller ones represent, in the mineral spinel, the magnesium atoms. Because there is one metallic ion surrounded by four oxygens arranged in a tetrahedron, this is said to occupy a tetrahedral interstice.

The other system of subcubes has the arrangement of Figure 3. Here the large circles and the small circles are as in Figure 2, oxygen and, for instance, magnesium. The black circles of intermediate size are, in the example taken, the aluminum ions. These latter positions are called octahedral positions because, if the total structure is considered, they lie in an octahedron with oxygen ions at the corners.

In the unit cell of a spinel there are therefore 32 oxygen atoms, eight tetrahedral holes, and 16 octahedral holes:

Tetra	Octa	Oxygen
8	16	32

The difference between a normal and an inverse spinel is in the distribution of the metallic ions over these positions.

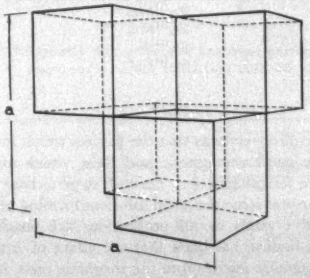


Figure 1. One set of subcells in spinel lattice unit cell

In a normal spinel the tetrahedral positions are occupied by the divalent ions and the octahedral positions by the trivalent ions. In an inverse spinel the tetrahedral positions are filled by the trivalent ions while the octahedral positions are occupied by both the divalent ions and the remainder of the trivalent ions.

One recent discovery has been that, of the cubic ferrites,

Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949.

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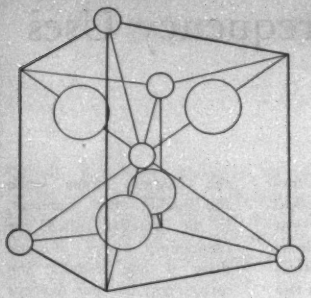

Figure 2. Arrangement of ions in tetrahedral cell

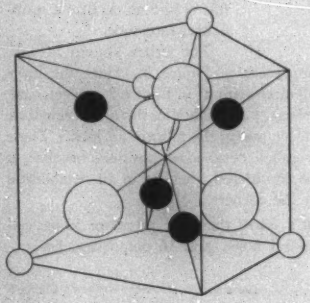

Figure 3. Arrangement of ions in octahedral cell

most of them are inverse spinels and some are normal. Thus:

Inverse:		
Tetra	Octa	Oxygen
Fe_8^{III}	$Fe_8^{III}Cu_8$	O_{32}
Fe_8^{III}	$Fe_8^{III}Mg_8$	O_{32}
Fe_8^{III}	$Fe_8^{III}Mn_8$	O_{32}
Fe_8^{III}	$Fe_8^{III}Ni_8$	O_{32}
Fe_8^{III}	$Fe_8^{III}Fe_8^{II}$	O_{32}
Normal:		
Zn_8	Fe_{16}^{III}	O_{32}

Another discovery was that the ferrites which are normal spinels are nonferromagnetic and those which are inverse spinels are ferromagnetic. Because these ferrites are all of the same crystal structure, solid solutions forming homogeneous mixed crystals in all proportions are possible. An important finding has been that the effect of introducing the nonmagnetic ferrites into the magnetic ones in homogeneous mixed crystals is to lower the Curie temperature.

One other fact has been established. Of the ferromagnetic ferrites all have negative magnetostriction excepting one, ferrous ferrite. Of this the magnetostriction constant is positive. In the development of ferromagnetic materials a useful expression has been developed by Becker and Kersten[7] for the maximum initial permeability:

$$\mu_{0max} = \frac{I_{sat}}{\lambda^2 E}$$

where I_{sat} is the intensity of magnetization at saturation, λ is the magnetostriction constant, and E is the modulus of elasticity.

This expression is considered by Snoek to require amplification to include the effect of crystal anisotropy and he writes:

$$\mu_{0max} = \frac{I_{sat}}{\lambda^2 E + K}$$

where K is some function of the crystal anisotropy.

Thus, to obtain a maximum initial permeability it is necessary to reduce both the magnetostriction and the crystal anisotropy to low values.

These two conditions can be met in solid solutions of mixed ferrites. The magnetostriction can be minimized by mixing positive and negative magnetostrictive ferrites. At the Curie temperature magnetic anisotropy disappears and below this temperature, but near to it, the anisotropy is reduced. So by introducing zinc ferrite, this factor can be minimized.

It is by these means, that is, reducing magnetostriction and the crystal anisotropy to low values, that high-permeability ferrites have been developed.

CHARACTERISTICS OF THE MATERIALS

The real advantage of these materials is obviously their low electrical conduction and therefore low eddy current losses at higher frequencies. Compared with iron, the

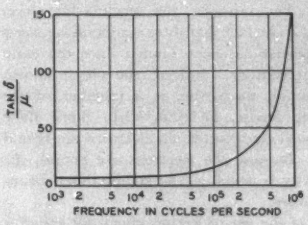

Figure 4. Loss factor versus frequency for FERROXCUBE III

Figure 5. Various circuit components made with FERROXCUBE III cores

Table I. Comparison of Dust Cores With Experimental FERROXCUBE Cubes

Dust Cores	μ	$a\times10^4$	$c\times10^4$	$e\times10_6$
Grade B iron	35	49	109	88
Grade C iron	26	81	139	31
81 Permalloy	75	5.5	37	51
2-81 Mo-Permalloy	125	1.6	30	19
Solid Cores				
Ferroxcube 1a	1,500	15		
Ferroxcube 1b	600	10		
Ferroxcube 2	400	10		
Ferroxcube 3	2,000	1		
Ferroxcube 4	80			

Table II. Comparison of Dust Cores With Experimental FERROXCUBE Cores

	Resistivity	$\frac{\tan\delta}{\mu}\times10^6$		
	ohm-cm.	10 kc	100 kc	1 mc
Grade B iron	10×10^{-4}	208	1,450	14,000
Grade C iron	10×10^{-4}	152	600	5,000
81 Permalloy	16×10^{-4}	92	820	8,000
2-81 Mo-Permalloy	40×10^{-4}	34	276	2,700
Ferroxcube 1a	$\sim10^6$	51	180	
Ferroxcube 1b	$>10^6$	168	100	100
Ferroxcube 2	$>10^6$	35	60	130
Ferroxcube 3	$\sim10^8$	8	17	174
Ferroxcube 4	$>10^6$	30	50	54

Table III. Typical Properties of Commercial FERROXCUBE III

μ_i, Initial permeability 600
μ_m, Maximum permeability 1,000
ρ, Resistivity, ohm-centimeters 100
$4\pi I_s$, Saturation induction, gauss 3,000
d, Specific gravity 4.8

Losses: $\frac{R}{\mu fL} = aB_m + c + ef$

a 2×10^{-4}
c 33×10^{-4} up to 100 kc
e 0.5×10^{-9}

resistivities of these materials may be 10^7 to 10^{11} times as great.

In Table I are given comparative data for some dust cores which might be used in higher frequency applications and several types of mixed ferrites. These mixed ferrites are sold under the trade-mark FERROXCUBE. The coefficients given are the coefficients of Legg's equation for soft magnetic materials at flux densities low enough to obey Rayleigh's law. These are the hysteresis coefficient, a, the residual coefficient, c, and the eddy current coefficient, e. In Table II these comparisons are continued. Notice in particular the resistivities. The loss factors at three frequencies are given also.

The data just given are for experimental materials. Philips now is manufacturing in the United States and abroad a high-permeability FERROXCUBE of which the nominal properties are given in Table III. Above 100 kc the ordinary Legg equation no longer applies, and until recently the graph of Figure 4 was used to represent the loss factor as a function of frequency. However recent discoveries regarding the properties of this material make it necessary to revise this. The newer data in this respect will be found at the end of the article.

Data for commercial FERROXCUBE III are conservative and it is possible, using special precautions, to prepare a product with the properties shown in Table IV.

APPLICATIONS

These materials find their greatest usefulness at communications frequencies. They are not in general satisfactory substitutes for iron at commercial power frequencies since the saturation magnetization is lower than iron by a factor of about seven. At communications frequencies real advantages in performance and space saving are to be had in inductors, transformers, and so on.[8–11] Figure 5 is an illustration of various circuit components made around cores of FERROXCUBE III.

A NEW DISCOVERY

One phenomena which has been noticed in some of these materials is that at higher frequencies the permeability

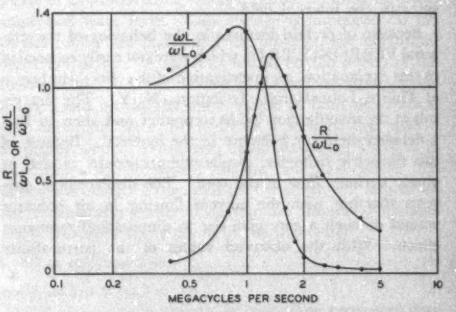

Figure 6. Frequency dependence of apparent permeability and apparent losses for FERROXCUBE III

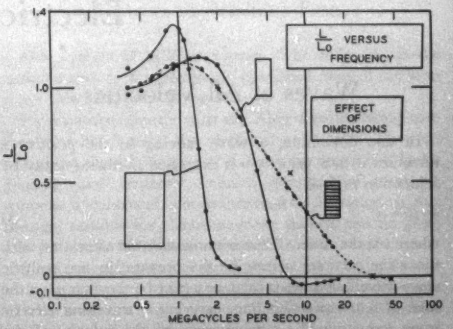

Figure 7. Effect of dimensional resonance in FERROXCUBE III upon apparent permeability

Areas marked off are core cross sections to scale

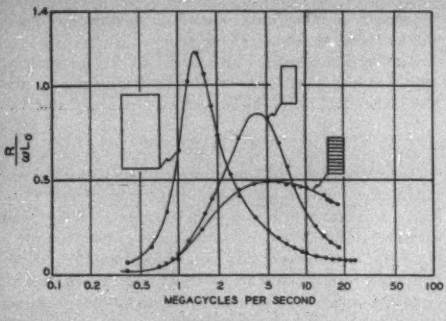

Figure 8. Effect of dimensional resonance in FERROXCUBE III upon apparent loss factor

appears to go rapidly to low values, as illustrated by Figure 6. This had been thought to be a manifestation of a resonance phenomenon occurring when the frequency of the applied field equals the precession frequency of the spins in the internal field.

Because of certain features in the behavior of the material FERROXCUBE III which were not easily reconciled to this explanation, an investigation of the effect was begun at Philips Laboratories, Irvington, N. Y. The net result of the investigation led us to predict and then to find a decided dielectric behavior in the material. Because of this dielectric behavior, displacement currents as well as ohmic currents flow in the core. The displacement currents together with the current flowing in an inductor wound on such a core give rise to dimensional resonance effects. With the observed values of the permeability

Table IV. Properties of Improved FERROXCUBE III

μ_0	1,000 to 1,500
tan δ/μ_i, 60 kc	0.08 to 0.12×10^{-4}
σ, 2 kc	1 to 4×10^{-9}

and of the dielectric constant, the velocity of propagation in the core may be such that core dimensions easily can be a half wave length at frequencies in the lower megacycle region.

It has been found that improved higher frequency performance can be obtained if the dimensions of the core in directions perpendicular to the flux are small compared with the wave length. Figure 7 shows how the observed permeability can be maintained to higher frequencies by this means. The areas marked off are the core cross sections to scale. In Figure 8 are given loss factors for these same cores.

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Electrical Essays

Waves of All Velocities

In one dimension, a wave moving in the positive x direction with a velocity v is expressed mathematically by a function such as

$$u=f(x-vt) \qquad (1)$$

where t is the time. Here u is any variable associated with the wave motion; u may be the pressure in an acoustic wave travelling down a tube, or u may be the charge on the wire of a transmission line, carrying a travelling electric wave, or u may be a component of the velocity of the points of a stretched string.

Whatever u may be, it is quite clear that the mathematical expression, equation 1, makes the instantaneous configuration of u as a function of x travel unchanged along the axis of x, with the velocity v.

In general, whatever the physical system may be which supports the waves given by equation 1, there is a so-called wave equation,

$$\frac{1}{c^2}\frac{\partial^2 u}{\partial t^2}=\frac{\partial^2 u}{\partial x^2} \qquad (2)$$

which is satisfied by the function u, and in which c is a number which is calculated from the system independent of the particular wave function.

Thus for acoustic waves of small amplitude in air, $c=\sqrt{\frac{1.4p}{d}}$, where p is the mean pressure and d the mean density

of the air; for the electromagnetic wave, $c=\sqrt{\frac{1}{\epsilon u}}$, where ϵ is the dielectric constant and u, the magnetic permeability of the medium; and for the transverse waves on a stretched string, $c=\sqrt{\frac{\tau}{\rho}}$ where τ is the mean tension, and ρ the density per unit length of the string.

It is generally believed that the combination of equations 1 and 2 requires that $v=c$, and therefore c is frequently called the velocity of sound, the velocity of electromagnetic waves or light, or the velocity of transverse displacement waves, as the case may be. However, actually, c in equation 2 is a material constant calculated from purely static measurements on the system. That $v=c$ is only a deduction made by humans and subject to the usual uncertainty of the correctness of deductions of human origin.

For larger numbers of dimensions, as for example three, we still have

$$u=f(x-vt, y, z) \tag{3}$$

representing a wave travelling in the positive x direction with velocity v. Clearly, equation 3 represents a spacial configuration, $f(x, y, z)$ moving with unchanging amplitude along the x axis with velocity v.

Likewise, for three dimensions, we have a so-called wave equation,

$$\frac{1}{c^2}\frac{\partial^2 u}{\partial t^2}=\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2} \tag{4}$$

where c is a constant calculated from purely static measurements on the medium carrying the waves, and u represented by equation 3 must satisfy equation 4.

Again, it is generally believed that for all free waves travelling in some particular direction, as for example in the positive direction of x as in equation 3, we must have $v=c$.

This belief is particularly prevalent for electromagnetic waves in free space. Also, since the advent of relativity, the belief is particularly strong that to have v greater than c is most absolutely impossible.

Nevertheless, it is quite possible to write down functions of the form equation 3 which satisfy equation 4 and for which v is not equal to c. Such a function is, for example,

$$u=A\sin\frac{2\pi}{\lambda}(x-vt)\cos\left(\frac{2\pi}{\lambda}\sqrt{\frac{v^2}{c^2}-1}\,y\right) \tag{5}$$

For v we may take any number greater than c, and equation 5 will still satisfy equation 4.

To illustrate equation 5 for electromagnetic waves, take an infinitely long row of long antennas each parallel to the z axis. Let the row be arranged along the y axis, and let successive antennas be $\frac{\lambda}{2\sqrt{\frac{v^2}{c^2}-1}}$ apart. Excite each antenna with currents of frequency $f=\frac{v}{\lambda}$, but make the phases of the currents in adjacent antennas be opposite. Then the radiation field from this system of antennas will have electric and magnetic field components which are closely given by equation 5 and, therefore, constitute a wave in free space, having a direction of free propagation, x, and a velocity v greater than c.

If the reader prefers that v be less than c, then he may take the function

$$u=A\sin\frac{2\pi}{\lambda}(x-vt)\cosh\left(\frac{2\pi}{\lambda}\sqrt{1-\frac{v^2}{c^2}}\,y\right) \tag{6}$$

Infinitely many other functions of the form equation 3 may be found which also satisfy equation 4 and for which v is not equal to c.

We conclude than that electromagnetic waves in free space exist which travel respectively with any and all velocities, v.

How about this?

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Lissajous Figure

Cathode-ray oscillographs are sometimes used to compare waves of two alternating voltage sources differing in phase angle and wave form. One voltage is impressed on the vertical deflection plates and the other on the horizontal deflection plates. A figure is traced on the screen of the oscillograph. It is well known that when the same voltage is impressed on the deflection plates in both the vertical and horizontal axes the figure is a straight line with a 45-degree slope. When two equal sinusoidal voltages in quadrature are impressed on the deflection plates, the figure is a circle. What well-known figure will appear on the oscillograph screen when the two impressed voltages are of the wave forms given in the following?

$$e_1=75\sin wt-25\sin 3\,wt \tag{1}$$

$$e_2=75\cos wt+25\cos 3\,wt \tag{2}$$

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Answers to Previous Essays

Flux Linkage of an Open Circuit. The following is the author's answer to a previously published essay of the foregoing title (*EE, Nov '49, pp 984–5*).

I sympathize greatly with my Alter Ego for being confused by his friends, the electrical engineers. They do talk about the flux linkage of an open circuit, as if it had a general, and perfectly definite quantitative meaning, whereas a consistent, contradiction-free definition of flux linkage, suitable for electromagnetic theory, can be given generally only for a *closed* curve or circuit.

That contradiction-free definition is that the flux linkage of a *closed* curve is the integral of the normal component of the magnetic flux over a simply-connected 2-sided surface bounded by the *closed* curve. If the curve is not closed then it does not bound any 2-sided surface, and there is no flux linkage. (Careful, Alter Ego! I do not mean here that the flux linkage is zero. What I do

mean is that the flux linkage is undefined and meaningless.)

Maxwell's equation, expressing Faraday's law of electromagnetic induction, given in modern vector analysis form is

$$\text{Curl } \boldsymbol{E} = -\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} \qquad (1)$$

where $\boldsymbol{E}$ and $\boldsymbol{B}$ are defined relative to some definite frame of reference.

"Curl" is a differential operation which can be defined independently of arbitrary co-ordinate axes, in terms of mathematical calculations from purely local observations or measurements of the vector $\boldsymbol{E}$ upon which "curl" operates. To determine the component in a given direc-

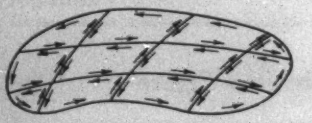

Figure 1. Surface built of surface elements

tion of curl $\boldsymbol{E}$ at a given point, consider a small "element of surface" at the point, perpendicular to the given direction; integrate $\boldsymbol{E}_s$ around the small *closed* curve bounding the "element of surface"; divide the value of this integral by the area of the bounded "element of surface"; take the limit of this quotient, as the "element of surface," retaining its orientation, approaches zero, the bounding curve converging on the given point. This limit is the value of the component in the given direction of curl $\boldsymbol{E}$ at the given point.

This definition of curl $\boldsymbol{E}$ makes equation 1 essentially equivalent to the following statement. For a small enough "element of surface," the integral of $\boldsymbol{E}$ around the small bounding curve is equal to $-1/c$ times the rate of change of the normal component of $\boldsymbol{B}$ multiplied by the area of the "element of surface."

We may build up large surfaces by the juxtaposition of these infinitesimal "elements of surface" as shown in Figure 1 of this answer. Adding up each $\boldsymbol{B}_n$ multiplied by its little area, we get of course, $\int\int \boldsymbol{B}_n dS$, taken over the whole surface, and the preceding paragraph leads us to assert that $-1/c$ times the rate of change of this surface integral is equal to the sum of the integrals of $\boldsymbol{E}$ around the boundaries of the various "elements of surface." But these boundaries form a network, and we see that in forming the sum of the integrals of $\boldsymbol{E}$, we integrate over each internal network portion twice, first in one direction and then in the other, making the net contribution to the integral sum of each internal network portion exactly zero. We are then left with only the external network portions, which form precisely the bounding curve of the surface. Thus the sum of the integrals of $\boldsymbol{E}$ around the curves bounding the "elements of surface" is equal to the integral of $\boldsymbol{E}$ around the *closed* curve bounding the total surface.

Thus, we see how Maxwell's equation 1 leads uniquely and irrevocably to statements connecting the values of $\boldsymbol{E}$ on a *closed* curve, with the values of $\partial \boldsymbol{B}/\partial t$ on the enclosed 2-sided surface. The meaning of the differential operator "curl" as explained in the foregoing, shows that Maxwell's equation 1 cannot possibly yield any general relation concerning the values of $\boldsymbol{E}$ on an open curve.

If we accept Maxwell's equation 1 as representing correctly and completely Faraday's law of induction, then Faraday's law must make assertions concerning voltage induced, only in *closed* curved paths or circuits, and flux linkage has meaning relevant to Faraday's law only for *closed* paths or circuits.

For Alter Ego's open key ring, we may close the open turn by drawing an arbitrary curve from the one end of the turn to the other, forming a closed loop. Flux linkage will have meaning for this closed loop, and the induced electromotive force, that is $\boldsymbol{E}$ integrated around this loop will be different from zero only when the flux linkage is changing, which will be when Alter Ego pulls his magnetized ring across the arbitrary curve.

In the case of the engineers and their machine, let us assume that the coil turn in question is in the stator, so that we do not need to discuss the electromagnetic properties of moving bodies, which we hope to consider in later essays. To give their flux linkage meaning, the circuit or path can be closed by joining the two coil ends by a curve lying wholly in the simply connected space outside the machine. We then see that the flux linkage of this resultant closed path is independent of how we draw this closing curve, so long only as it lies wholly outside of the machine. Thus, with the understanding that the closing curve is to be drawn wholly outside the machine, the engineer may speak of the flux linkage and induced voltage of the machine turn.

Similarly, for the voltage induced in a transformer winding, not short-circuited upon itself, and therefore open, we must to be consistent mean the voltage induced, or $\int \boldsymbol{E}_s ds$ taken, around a *closed* path including the winding and some arbitrarily chosen closing curve lying wholly outside the transformer case.

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Network. The following is the author's solution to a previously published essay of the foregoing title (*EE, Nov '49, p 984*).

The impedance of the network in each box reduces to the same value and its performance is expressed by Heaviside equation:

$$(R+.8Lp)i = e\ 1$$

It is, therefore, impossible to detect by external measurements the nature of the internal connections in the box. Were iron core transformers used in the networks the one with series-connected windings would give the same performance as an air core transformer. All the phenomena associated with saturation, hysteresis, and residual flux will be present in the network with parallel connected windings of an iron core transformer and the detection of this connection is therefore possible by external measurements.

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Short-Circuit Currents and Recovery Voltages

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FIELD tests were made on a 7,200/12,470Y-volt multigrounded rural distribution system to check fault current calculations and to investigate transient recovery voltages experienced as a consequence of clearing fault currents. Tests were also made using a miniature circuit representation of a rural distribution system in order to investigate the effect of variations in circuit conditions incident to the fault. The use of the miniature system or transient analyzer made possible a determination of the order of magnitude of crest voltages and rates of rise that may be expected under most severe conditions. The work is expected to be of considerable value in the preparation of standards for the testing of such devices as expulsion lightning arresters and distribution fuse cutouts. In so far as the authors are aware, this is the first published information on transient recovery voltage tests on rural distribution systems and the correlation therewith of transient analyzer results.

Figure 1 shows typical oscillograms obtained in the field tests and with the transient analyzer with comparable circuit conditions.

The studies showed that the transient recovery voltages experienced are affected in varying degrees by numerous factors. Some of the more important factors are

1. The length of line remaining connected to the substation after fault interruption.
2. The distance between the substation and the fault.
3. The X/R ratio of the line between substation and fault.
4. Arc voltage characteristics of the fault clearing device.
5. Complexity of system network.
6. Damping due to system load connected after fault interruption. See Figure 2.
7. Kilovolt-ampere capacity of substation transformer bank.
8. Lumped capacitance between line and ground in substation bus structure or power factor capacitors.

During field tests, the highest crest voltage measured was 1.33 times normal crest voltage and occurred when a fault about 16 miles from the substation was cleared by a line sectionalizing recloser. This value is somewhat higher than most of those obtained in the field tests and appeared to be due primarily to an unusually rapid rise in arc voltage in the sectionalizing device just prior to clearing.

The most rapid rate of rise of recovery voltage recorded in the investigation occurred during field tests for a fault at the substation which was cleared by the main substation sectionalizing fuse leaving no connected line. It rose to 0.9 normal crest voltage in 22 microseconds. In this case, the crest recovery voltage was only 0.94 times normal.

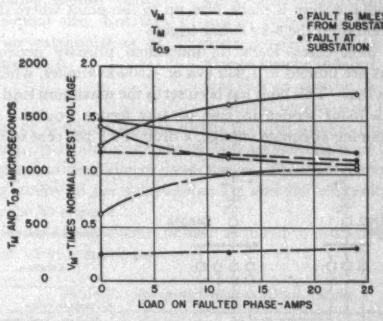

Figure 2. Effect of load on recovery voltage characteristics; transient analyzer results from simulated field system

V_M—times normal crest voltage; T_M—time to crest recovery voltage; $T_{0.9}$—time to 0.9 of normal crest voltage

When more severe circuit conditions were investigated using the transient analyzer, crest recovery voltages of the order of 1.75 times normal were obtained. These values occurred with six miles of unbranched line connected after the fault, and 50 kva of transformer capacity. As the kilovolt-amperage was increased to 2,000, with other factors constant, the crest voltage dropped to 1.28, but the rate of voltage rise increased so that 0.9 normal voltage was attained in 80 microseconds as compared with 280 microseconds with a 50-kva bank.

Short-circuit currents recorded in field tests were in excellent agreement with those calculated by means of simplified methods using special graph paper and template. The value of the transient analyzer in investigating transient characteristics was amply demonstrated.

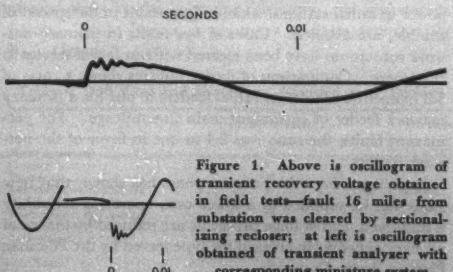

Figure 1. Above is oscillogram of transient recovery voltage obtained in field tests—fault 16 miles from substation was cleared by sectionalizing recloser; at left is oscillogram obtained of transient analyzer with corresponding miniature system

Digest of paper 49-177, "Short-Circuit Currents and Recovery Voltages on a Rural Distribution System," recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Washington 4-Kv Primary Network Systems

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THE POTOMAC Electric Power Company started the use of 4-kv primary networks about 1939. Since that time the procedure has been to prevent load growth on existing substations supplying 4-kv radial feeders by establishing primary networks in the outlying portions of the areas served by the existing radial stations. It is in these areas that the load growth is most rapid. Studies have shown that, with distributed load, this method is more economical than expanding the use of 4-kv radial feeders if the radial system is made firm up to the point where distribution from the 4-kv feeder begins.

In most cases, loads on individual primary network feeders are limited to 1,800 kva or 4,500-kva miles, whichever is less. This limit has been set as the maximum load or area without service in case of 4-kv feeder trouble. In maintaining adequate voltage, a drop of 2.5 per cent in the reason, they are placed in buildings which resemble typical $1^1/_2$-story homes. Special attention is given to appearance and quietness of operation. Where a building is not required for appearance, an outdoor station is used. In this case, three shot reclosing fuses have been used in place of feeder circuit breakers. An automatic circuit breaker is installed for the transformer secondary.

The transformer circuit breaker is arranged to reclose automatically when the proper voltage and phase rotation appears on the transformer secondary terminals. It will trip on reverse current or in case of a ground on the high-voltage supply feeder. In case of operation of the transformer overcurrent relays, indicating a bus fault, the circuit breaker will lock out and an auxiliary relay will trip the feeder circuit breakers where such breakers are used.

By the use of the primary network, the number of circuits

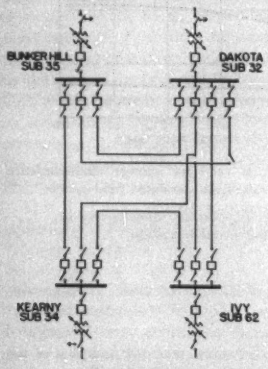

Figure 1. Primary network system supply, Brookland area

Table I. Comparison of Operating Performance

4-Kv Radial Versus Network Feeders

Location	Years	Miles	Number of Tripouts	Number of Interruptions	Per Mile-Year Tripouts	Per Mile-Year Interruptions
OVERHEAD AREA						
Radial: Tenleytown	1	11.6	13	3	1.1	0.26
Network: Tenleytown–Wesley	1.0	8.9	5	3	0.56	0.34
Radial: Brightwood–Brooklyn	3.0	29.4	75	30	0.85	0.34
Network: Brooklyn	3.0	12.4	11	7	0.29	0.19
Radial: Riverdale	3.0	25.7	95	41	1.23	0.53
Network: Riverdale–Sunnyside	3.0	15.8	0	2	0	0.04
Radial: Anacostia	3.0	4.7	9	0	0.64	0
Network: Anacostia–Hillcrest	3.0	10.6	13	4	0.40	0.13
Average: Radial overhead	3.0	71.4	218	80	1.02	0.37
Average: Network overhead	3.0	47.6	39	22	0.27	0.15
Advantage factor favoring overhead network					3.8	2.4
UNDERGROUND AREA						
Radial: Eastern	3.0	18.6	12	31	0.21	0.55
Network: Southeast–Southwest	3.0	23.2	11	6	0.16	0.09
Advantage factor favoring underground network					1.3	6.1

4-kv primary under normal conditions is the limit for suburban and urban areas. Under emergency conditions, such as the loss of a substation or opening of one end of the 4-kv feeder, primary voltage is permitted to drop to 89 per cent of normal. Fixed capacitors on feeders and both fixed and switched capacitors in the substations are used to maintain satisfactory voltage and to increase the kilovolt-ampere mile loading of feeders over this limit. Typical primary network stations have four feeders and are located at strategic road intersections.

Most stations are located in residential zones, and for this on any pole have been materially reduced over those required for large radial substations. This avoids unsightly conditions which might otherwise result in the large expense of placing lines underground. Large concentrations of power in radial stations, which might result in the spread of trouble, are avoided. Cases of bus faults in primary network substations have been cleared without loss of service to customers. Comparison of feeder outages shows a ratio of 3.8 momentary faults on radial feeders to one for a primary network feeder of equivalent main line mileage. For permanent faults, the ratio was 2.4 to one in favor of the network feeders.

Experience over the past ten years has shown that new loads can be supplied at a lower cost, operating reliability is improved, and voltage problems are reduced by the use of primary networks in areas of the type served by the Potomac Electric Power Company.

Digest of paper 49-180, "Design and Experience with 4-Kv Primary Network System in the Washington Area," recommended by AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Low-Cost Conductive Flooring for Hospitals

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A new type of electrically conductive flooring for use in hazardous locations in hospitals is designed to prevent the accumulation of electrostatic charges on personnel and equipment which would create an explosion hazard in areas where combustible anesthetics are stored or used. This discussion of the characteristics desired in such flooring, and of the results of tests which have been made, should prove interesting not only for hospital use, but for many other purposes, as an extrapolation of the basic principle.

STATIC ELECTRICITY has been identified as the cause of more than one-quarter of the explosions of anesthetic gases in operating and delivery rooms.[1] Since nearly all of the remainder were traced to equipment, static electricity emerges as the chief danger which the designers and builders of hospitals must overcome. The use of conductive flooring to carry off, neutralize, or prevent the accumulation of static charges on personnel and equipment is now generally accepted.

This article discusses the characteristics desired in conductive flooring, and presents the results of tests on two materials which are believed to meet the recommendations of the National Fire Protection Association at a cost little greater than that of ordinary tile or terrazzo.

FUNCTIONS OF CONDUCTIVE FLOORING

The resistance of conductive flooring should be adjusted to serve two purposes. It should be low enough to carry off static charges to prevent electrostatic sparks which might cause explosions. It should, at the same time, be high enough to minimize shocks to operating personnel where a grounded electric wiring system is present. It should be remembered, however, that even a mild shock may cause an involuntary reaction which might easily have serious consequences during a delicate operation.

In addition to electrical characteristics, the floor should be sufficiently durable for the intended service.

CAUSES OF EXPLOSIONS IN HOSPITALS

An explosion will result when the temperature of a flammable mixture of a combustible gas with air or oxygen reaches the flash point. There are several possible causes of explosions in the operating, delivery, and gas storage rooms. Table I gives a summary of cases reported by B. A. Greene.[1]

Table I. 230 Fires and Explosions, Grouped as to Etiology

	Number of Cases	Per Cent
X-ray apparatus	10	4.35
Cautery	57	24.80
Diathermy	20	8.70
Suction-pressure machines	59	25.62
Endoscopic apparatus	5	2.17
High-pressure explosions	10	4.35
Static electricity	63	27.40
Miscellaneous	6	2.61
Total	230	100.00

Explosions caused by apparatus are usually traceable to faulty equipment or use of equipment of a design not suitable for use in hazardous areas. Most of these faults may be isolated and eliminated. Static electricity is a source of fire hazard requiring special attention as there are many ways in which the static charge may be induced. The fact that an electric charge is produced on any object, person, or material, usually means that the process will continue, more and more charge will accumulate until finally the mutual repulsion of these charges will exceed the insulating ability of the surrounding air and the electricity will escape as a spark.[2]

Table II shows crest voltage required to produce sparks with varying spark gaps.

Table II. Sparking Voltages (Crest Value)

Gap, Centimeters	Volts—on Sphere 0.25-Centimeter Diameter	Volts—on Sphere 1.0-Centimeter Diameter
0.01	1,080	860
0.05	2,920	2,780
0.1	4,730	4,670
0.2	8,340	8,080
0.5	15,800	17,400
1.0	20,500	29,800
1.5	22,900	39,900

STATIC AND SHOCK PREVENTION

Basically with all materials, equipment, and persons effectively grounded, or in electrical contact with each other, no difference in electric potential between such interconnected objects and persons could be accumulated and there could be no sparks from electrostatic charges.

The most effective way to prevent the accumulation of electrostatic charges in operating rooms is to provide an electrically conductive path, of relatively low resistance, between each object and each person in the room. The most practical and convenient conductor between people and equipment is the floor. To assure electrical contact with the floor, all persons in the room should wear shoes with conductive soles or the equivalent. All equipment including all integral parts such as casters, table leg tips, and so forth, should be of metal, conductive rubber, or

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other conductive material, except parts of electric equipment required to be insulators.

While low resistance is ideal for conducting off the static charges, the best safety precaution against electric shock to operating persons is perfect insulation or very high resistance. Should the wiring in the operating room be of the usual 115 volts with one wire grounded, operating personnel using or handling electrically operated equipment or apparatus may, through faulty equipment or by accident, come in contact with an uninsulated power conductor, and if they are at that time in contact with the grounded floor of very low resistance, they will receive an electric shock. The severity of the shock will depend upon the amount of current and its path through the person's body. For a given voltage, the amount of current is limited by the resistance of the conducting path to ground, which includes the resistance of the person's body, shoes, and conducting floor. If the resistance of the conducting path is sufficiently high, the person will feel no shock. A very low resistance will allow currents to flow which may produce burns, a painful shock, a combination of both, or death.

PERMISSIBLE FLOOR RESISTANCE

As a protection against sparks from electrostatic discharges which may result in fires or explosions of combustible anesthetic agents, the National Fire Protection Association[3] has recommended that the resistance of the floor to ground should not exceed 250,000 ohms, measured from any position on the floor to ground, with an electrode that will exert a force of five pounds uniformly over a circular area of five square inches. These present recommendations do not include a lower limit of resistance for protection against electric shock. However, it is reported that a lower limit of resistance is being considered for incorporation into these recommendations. It is also reported that consideration is being given to the possibility of a safe top limit of resistance greater than 250,000 ohms. Charles F. Dalziel has conducted experiments to determine the minimum current that will produce shock.[4] Using 60-cycle current, 114 men were tested to determine the perception point. The lowest current perceived by any of the 114 men tested was 0.3 milliampere. The average perception point for 50 per cent of the persons tested was about 1.0 milliampere. It is important that operating personnel should not be subjected to a shock of an intensity which would divert their attention from their work. Electric currents which barely can be detected by a person taking a perception test would normally be unnoticed by the same person concentrating upon another task; therefore, it is evident that the minimum perception current would not constitute a danger.

The resistance of the human body circuit when the skin is dry may be as high as 500,000 ohms. With the point of contact wet by salt solutions or perspiration, as may be the case with operating personnel, the resistance may be as low as 1,000 ohms. NFPA[3] recommends that shoes of operating personnel should have soles and heels of conducting material of not more than 250,000 ohms measured under conditions of pressure and contact area simulating normal use of the shoes. However, the resistance of operating shoes may vary considerably and it is estimated their resistance may be as low as 10,000 ohms. The remaining part of the conductive circuit to ground is the floor which, for ideal conditions, should have a resistance of such value that the total resistance of person, shoes, and floor will limit the current to a value of about 1.0 milliampere.

As an example, assume that the operating room is wired in the usual manner with 115 volts with one wire grounded, and a person contacts an uninsulated power conductor of 115 volts. The floor resistance necessary to limit the current to 1.0 milliampere may be calculated by Ohms law: $I = E/R$, or $0.001 = 115/1{,}000 + 10{,}000 + R$ (floor); or R (floor) = 104,000 ohms. A floor resistance of 250,000 ohms maximum recommended by NFPA, and other conditions as stated in the foregoing will permit a current of about 0.44 milliampere which can be perceived by only about 1.0 per cent of average men. It follows that a flooring with a resistance of from 104,000 to 250,000 ohms would provide the maximum protection from the combined dangers of static sparks and shock. The nature of floors and their normal usage are such that it is difficult to construct and maintain them so they will remain within these ideal limits of resistance under all usage conditions. Therefore, a compromise of a resistance range of about 25,000 ohms as the lower limit and about 250,000 ohms as the upper limit appears practicable for actual commercial construction.

CONDUCTIVE FLOORING—TILE AND TERRAZZO

Many architects, doctors, and hospital administrators prefer tile or terrazzo floors in hospital operating suites, but normally these floors are not electrically conductive. It was found that metallic particles and carbon of varying proportions had been used in tile, clay, concrete, and terrazzo without producing a satisfactory floor material. While it had been determined that carbon black derived from coal, petroleum, and natural gas was not suitable, it was noted that carbon black specially prepared from acetylene formed a different pattern when mixed with other materials such as rubber. The acetylene particles in mixtures formed chains instead of groups. Tests made by the Bureau of Standards of small samples of concrete into which small quantities of acetylene carbon had been mixed indicated that the concrete mixture was electrically conductive and that its physical properties would meet most normal floor requirements.* It was then concluded that the chain formation of acetylene carbon in concrete would form an electrical path from the floor surface when used in tile joints and underbed, and in the terrazzo mix. For an initial test three samples each of terrazzo and ceramic tile floors were prepared in an effort to develop conductive flooring materials which will comply with the recommendations of NFPA[3] and provide the most effective compromise between protection against electrostatic sparks, flashes from accidental grounding of electric conductors, and electric shock to operating personnel. These samples were constructed as in commercial practice except that a specially prepared acetylene carbon black (hereafter referred to as

* Tests on Conductive Flooring, 1942, for United States Army Corps of Engineers. Test data not published. National Bureau of Standards, Electrical Instruments Section, Divison of Electricity.

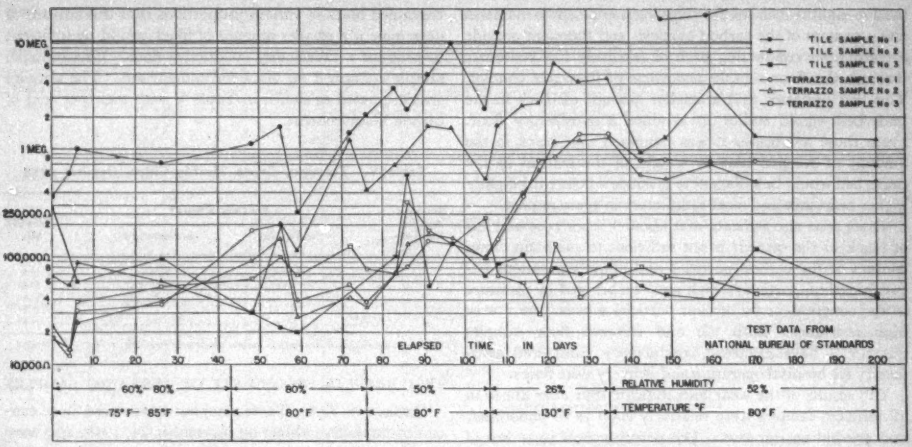

Figure 1. Electrical resistance of flooring—special samples of tile and terrazzo

black) was added to the cement mixture as a conducting medium. A wire mesh was embedded in each sample for ground or test connection. The black was weighed and mixed dry with the cement and then the cement and black mixture thoroughly mixed with the sand before water was added.

These samples were proportioned as shown in Tables III and IV.

Table III. Terrazzo, White Marble Chips, May 1947

Sample Number	Per Cent of Black* in Topping	Per Cent of Black* in Underbed	Underbed Mix
1	0.5	2.5	1:4
2	1.0	5.0	1:4
3	2.0	10.0	1:4

* Per cent by weight of Shawinigan carbon black to dry cement.

Table IV. Ceramic Tile, One Inch by One Inch Floor Tile, June 1947

Sample Number	Per Cent of Black* in Joint Grout	Per Cent of Black* in Underbed	Underbed Mix
1	0.9	0.6	1:2
2	2.0	3.0	1:2
3	4.0	6.0	1:2

* Per cent by weight of Shawinigan carbon black to dry cement.

Black in the cement mixture causes a grey color varying in hue with the amount of black added. In terrazzo, the dark color of the cement mixture may be partially counteracted by white or light colored marble chips. In tile floors, the dark color in the joint grout is considered a desirable feature to break the monotony of a solid color. As the conducting surfaces of the tile floor are in the joints, the surface resistance may be varied by using smaller or larger tile.

TEST RESULTS

These floor samples were tested by the National Bureau of Standards,* for electrical conductivity in a manner prescribed by NFPA,[3] and for abrasive hardness by using alundum abrasive in the Kessler wear test apparatus described in the National Bureau of Standards Research Paper *RP612*. Electrical conductivity tests were run under controlled relative humidity conditions varying from about 80 per cent to 26 per cent. The series of tests extended over a period of about 8 1/2 months from the date samples were constructed.

The results of the conductivity tests, plotted on graph, Figure 1, indicate that during the first two months of test and while the humidity was maintained at about 80 per cent relative humidity, the resistance of all samples was fairly uniform and with the exception of number 1 tile and the initial reading of number 3 tile, was well within the recommended maximum 250,000 ohms. As the humidity was decreased and the samples reached a more permanent state, the resistance of the various samples became more widely separated, some reaching a very high value, showing that the original conductivity registered was largely due to moisture in the samples. Only samples number 3 of both tile and terrazzo had a fairly uniform resistance throughout the test, and remained well within the recommended maximum 250,000 ohms except for one slightly high point on the graph for terrazzo and two slightly high points for tile. These may have been due to test procedure or poor contacts of the testing equipment, or to imperfect samples. Samples 1 and 2 of both tile and terrazzo reached a resistance value far above 250,000 ohms and these are not considered unsatisfactory for hospital operating room floors.

Test results of these initial samples indicate that black in the amount of 2.0 per cent by weight of the cement in

* Tests of conductive floor samples submitted by Public Health Service, Division of Hospital Facilities, April 1947. National Bureau of Standards. Conductivity test: Electrical Instruments Section. Abrasive hardness: Building Stone Section.

the five-eighths-inch terrazzo topping is sufficient to maintain chain contact of the carbon particles and therefore provide a continuous conducting path of relatively low resistance through the floor sample regardless of its water content. This fact indicates that a smaller amount of black in the underbed would suffice to produce a satisfactory floor. From these test results it was estimated that black in the amount of 3.0 per cent by weight of the cement in the underbed would be sufficient to produce a floor with slightly higher resistance and more satisfactory in every respect.

These tests also indicate that about 1.0 per cent and less of black in the cement is not sufficient to maintain chain contact of the carbon particles and allow separations between carbon particles which must be bridged by moisture in the concrete, or by cement particles which have a very high resistance. Both tile and terrazzo floor samples number 3 have electrical conductivity considered satisfactory for hospital operating and delivery suite floors.

The results of the wear tests indicate that after abrasion all terrazzo samples were relatively good as to smoothness and general appearance. The percentage of wear loss of tile was considerably less than that of terrazzo; however, the tile had not bonded well with the mortar and for that reason these samples were not satisfactory. A different type of cement was used in the tile setting than that of the terrazzo, and the poor bonding of the tile is believed to be caused by the cement or the method of construction. As a recheck on the bonding qualities another tile sample was constructed on September 3, 1948, in the same weight proportions and similar to the original tile sample number 3, except that standard Portland cement was used in both underbed and grout to which black was added at the rate of 2.0 per cent by weight of dry cement. Since construction, the sample has aged in an air-conditioned building where the relative humidity is maintained at 50 per cent. The room relative humidity and the sample resistance have been checked at random for a period of about ten months. The electrical resistance so measured has remained less than 250,000 ohms and has been essentially the same as the original tile sample number 3 when its age and surrounding conditions were comparable. The bond between mortar and tile of the new sample has been tested and appears satisfactory.

TEST SAMPLES, SECOND SET OF TERRAZZO

From information obtained through tests of the first set of samples, additional terrazzo samples were constructed in October 1948 under the direction of a committee of government agencies* interested in hospital safety construction. These samples were also tested at the National Bureau of Standards for the same qualities and in a manner similar to that described except that additional tests were conducted to determine the modulus of rupture, absorption, bulk density, and the effects of detergents.

One of these samples contained black in the proportion of two per cent by weight of cement in topping and three per cent by weight of cement in the underbed as estimated to be satisfactory from the initial tests. Other samples contained black of various proportions near this amount to determine if a smaller amount of black would be sufficient to produce a satisfactory conductive floor. One terrazzo sample contained no black for comparison. The samples are designated as shown in Table V with their per cent of carbon black content.

* Committee on Explosions in Hospital Operating Rooms. Agencies represented are: Army Corps of Engineers; Bureau of Mines; National Bureau of Standards; Navy Department; Public Buildings Administration; Public Health Service; Veterans Administration.

Table V. Terrazzo, Green Marble Chips, October 1948

Terrazzo Sample Number	Per Cent of Black* in Topping	Per Cent of Black* in Underbed	Underbed Mix
1C	None	None	1:4
1	1½	2	1:4
2	2	3	1:4
3	2	2	1:4
4	1½	3	1:4

* Per cent by weight of Shawinigan carbon black to dry cement.

TEST RESULTS, SECOND SET OF TERRAZZO SAMPLES

Conductivity Test. These samples were stored in a controlled-humidity cabinet on November 24, 1948, and were tested weekly in a manner prescribed by NFPA.[3] For each measurement of resistance the electrode was successively placed at ten different locations on the surface of the sample and the results were averaged. To accelerate the normal aging and drying, a low ambient humidity and a moderately high temperature were maintained in the cabinet for an extended period. This was followed by a period of conditioning at a moderate humidity. The results of these tests are shown in Figure 2. They confirm the results of earlier tests shown on Figure 1 by showing that the resistance of the samples is dependent upon the age and moisture content of the material. They show that the resistance of dry concrete without black is too high to meet NFPA[3] recommendations and that at reasonable humidities the resistance of concrete with two per cent of black added to the cement in the topping is low enough to meet the NFPA recommendations.

In addition to the usual testing for resistance through the floor surface, resistance measurements were made with the electrode placed on the back surface of the underbed. They showed that the resistance of the underbed was negligible when compared with the resistance of the topping of each sample. The large differences in resistance observed between samples which have the same nominal amount of black in the topping is probably due to differences in the actual proportions of black to cement used or differences in dispersion of the black in the topping. From these tests it would appear that concrete containing either two per cent or three per cent of black to dry cement, by weight, should be equally satisfactory in the underbed. However, the resistance of samples with only two per cent black in the underbed exceeded the maximum resistance recommended by NFPA.[3] To allow for such variations in construction three per cent of black to dry cement in the underbed should be used, where the floor is required not to exceed 250,000 ohms.

Physical Properties. Tests for physical properties show that with two per cent black added to cement, the wearing surface or topping compares with plain terrazzo as follows: The modulus of rupture is reduced about 6 per cent, the

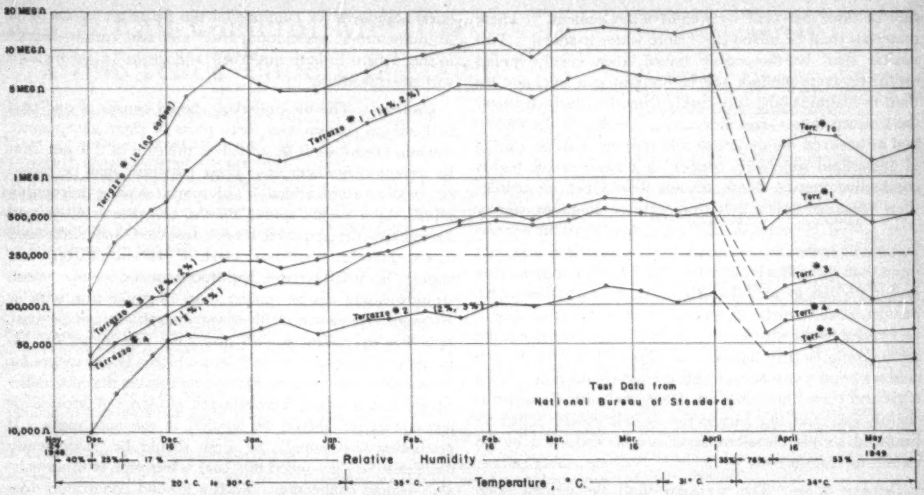

Figure 2. Electrical resistance of flooring—special samples of terrazzo

per cent absorption is increased about 22 per cent, the bulk density is increased about 1.0 per cent, and the abrasive hardness is reduced about 37 per cent.

Although the addition of carbon black reduced the wear resistance, it is evident that this can be overcome to a great extent by using hard marble chips. In any case, with two per cent black added, the wear resistance seems to be sufficient for hospital operating suites.

Tests to determined the injurious effects of detergents commonly used for floor washing are well advanced but not complete. To date the terrazzo samples containing black, and also the plain terrazzo samples with no black, have withstood more than 192 cycles of treatment without disintegration. In earlier tests[7] plain terrazzo, without black, disintegrated at 280 cycles of similar treatment. The detergent test records and also visual inspection shows negligible difference in the effects of detergents between samples with two per cent and those with no black.

CONCLUSIONS

The results of tests described herein indicate that by the addition of carbon black to cement mixtures, floors of hospital operating and delivery suites can be economically constructed which will combine the following qualities:

1. Conformity with the recommendations of NFPA for maximum allowable resistance for control of static electricity.

2. Approximately uniform electrical conductivity over the entire floor surface to prevent the accumulation of static charges of sufficient voltage to cause sparks.

3. Resistance high enough to protect personnel from severe electric shock.

4. Prevention or minimization of sparks which might be caused by grounding or short-circuiting electric cords to the floor where wiring is of a grounded electric system.

5. Wearing and strength qualities, and resistance to detergents sufficient for hospital operating suites.

6. Color of varied designs sufficiently light to meet the architectural requirements.

7. A floor of which the electrical resistance is not seriously affected by changes in humidity, and which in itself is conductive regardless of its moisture content.

RECOMMENDATIONS

General. Hospital operating and delivery suites, anesthesia storage rooms, and all locations classified by the National Electrical Code as "Class I Group C Hazardous Locations" should have electrically conductive floors. The floor as normally contacted with a person's shoe, furniture, table leg tips or casters, should be approximately uniform in conductivity over its entire surface. The floor resistance should be low enough to conduct off and prevent the accumulation of electrostatic charges, and at the same time the resistance should be high enough to protect operating personnel from severe electric shock. The floor should be sufficiently durable for its intended use and should have electrical characteristics which conform to the latest recommendations of the National Fire Protection Association.

TERRAZZO (BASIC GUIDE SPECIFICATIONS)

Construct as in commercial practice in accordance with the standards established by the National Terrazzo and Mosaic Association, Inc.[5] except that carbon black* shall be added to the cement in both underbed and topping, and other special requirements, as specified in the following.

Underbed. The terrazzo underbed shall consist of one part of Portland cement and four parts coarse screened sand. Carbon black shall be added to the cement at the

rate of three per cent by weight of dry cement.* These materials shall be mixed dry before water is added. This mortar shall be thoroughly mixed, then evenly spread on the concrete subfloor and be brought to a level not less than five-eighths inch (preferably three-fourths inch below the finished floor. Installed and embedded in the underbed or between the underbed and topping shall be a mesh of galvanized iron wire, copper, or other suitable highly conductive metal. Mesh strands should not be smaller than 18-gauge galvanized iron wire or 20-gauge copper wire. Mesh openings should be not more than the equivalent of two inches by two inches for 18-gauge iron wire, nor more than six inches by six inches for 20-gauge copper wire, and in no case greater than six inches by six inches where heavier mesh is used. A ground or test connection should be bonded to the wire mesh. If grounding is required, the mesh should be permanently and effectively grounded to a cold water pipe or other suitable ground connection. Such a ground connection does not affect the static hazard but slightly increases the hazard for electric shock, unless an insulated supply circuit is used such as furnished by an insulating transformer.

Dividing Strips. The terrazzo shall be jointed with plastic or other similar nonmetallic dividing strips not less than $1\frac{1}{4}$ inches deep, and forming squares of from two feet to three feet in each direction. While the underbed is in a semiplastic state, the divider strips shall be installed into the underbed so that the top edges will be flush with the finished floor surface.

Topping. The terrazzo topping shall consist of one part Portland cement and two parts marble granule, by weight. Carbon black* shall be added to the cement at the rate of 2.0 per cent by weight of dry cement, then all materials shall be mixed dry before water is added. The marble granule portion should be made up with one part of number 1 granules and one part of number 2 granules of any desired color. Placing and finish of this mixture should conform to the requirements for standard terrazzo work, as in commercial practice.

CERAMIC TILE (TENTATIVE GUIDE SPECIFICATIONS)

Recommendations for ceramic tile floors for "Class I Group C Hazardous Locations" were originally withheld pending further investigation into the bonding of such floors. A subsequent sample has been constructed and informally tested, although not subjected to the complete tests given the original sample.

Inspection and informal tests, described earlier in this article, indicate that tile floors of the conductive type can be constructed and maintained satisfactorily.

Should tile floors of the conductive type be desired, the following special requirements and tentative specifications may be used.

General. Construct tile floors in accordance with the latest standards for commercial tile floors set by the Tile Manufacturers' Association, Inc.[6] and add carbon black* to the cement in both underbed and grout in accordance with specifications.

Underbed. The tile underbed should consist of one part of Portland cement and three parts of clean sharp sand. Carbon black* shall be added at the rate of 2.0 per cent by weight of dry cement. These materials shall be mixed dry before water is added. This mortar shall be thoroughly mixed, then evenly spread on the concrete subfloor and brought to the required level. Installed and embedded in the underbed shall be a mesh of galvanized iron wire, copper, or other suitable highly conductive metal. Mesh strands should not be smaller than 18-gauge iron wire or 20-gauge copper wire. Mesh openings should not be more than the equivalent of two inches by two inches for 18-gauge iron wire, nor more than six inches by six inches for 20-gauge copper wire, and in no case greater than six inches by six inches where heavier mesh is used. A ground or test connection should be bonded to the wire mesh. If grounding is required, the mesh should be permanently and effectively grounded to a cold water pipe or other suitable ground connection. Such a ground connection does not affect the static hazard but slightly increases the hazard for electric shock, unless an insulated supply circuit is used such as furnished by an insulating transformer.

Tile. The floor tile selected should be not larger than one inch by one inch surface.

Grout. The grout mixture for tile joints should be neat Portland cement with 2.0 per cent by weight of carbon black added to dry cement.

Finish. Grout in the joints should be finished flush with tile floor surface.

OTHER PROTECTIVE MEASURES

A satisfactory electrically conductive floor is a construction feature and a necessary part of the protective system to prevent static charges from building up to a potential sufficient to cause a spark which may result in an explosion; however, during use, other protective measures must be taken by the operating team, such as careful use of equipment, to assure maximum safety of patients and operating personnel in hazardous areas.

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3. Combustible Anesthetics in Hospital Operating Rooms. National Fire Protection Association, 1944.

4. Controlling Electrical Hazards, **Charles F. Dalziel.** *Electrical Engineering*, August 1947, pages 786–92.

5. Technical Data and Specifications for Terazzo and Mosaic Work. AIA File *23-B*. National Terrazzo and Mosaic Association, Inc. (Note that these specifications are for standard terrazzo work and that carbon black must be added to comply with these recommendations for conductive floors.)

6. Basic Specifications for Tile Work Number K-300. The Tile Manufacturers' Association, Inc. (Note that these specifications are for standard tile work and that carbon black must be added to comply with these recommendations for conductive floors.)

7. Terrazzo as Affected by Cleaning Materials, **D. W. Kessler.** Title Number *45-3*, *Journal* of the American Concrete Institute, volume 20, number 1, September 1948. *Proceedings* volume 45.

* Carbon black shall be of a special form produced by the thermal decomposition of acetylene gas under carefully controlled conditions. One source of supply is Shawinigan Products Corporation, Empire State Building, New York, N. Y. The product name, "Acetylene Black," is manufactured in only one grade but is packed both 50 per cent and 100 per cent compression, either of which is satisfactory. Its cost is about 19 cents per pound f. o. b. Jersey City, N. J. Other sources of supply of carbon black of equal grade and specifications will be acceptable. It should be noted that carbon black of petroleum derivatives is not suitable.

AIEE Fall General Meeting Conference Papers Digested

These are authors' digests of most of the conference papers presented at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. The papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

Determination of Reserve Capacity by the Probability Theory—Simplified Methods, Indexes of Service Reliability; *G. Calabrese (New York University, New York, N. Y.).*

This paper, a sequel to the paper presented by the author at the Midwest General Meeting in Chicago in the fall of 1947, has the following objectives:

1. The development of formulas for calculating indexes of service reliability, assuming a straight line load duration curve.

2. A comparative discussion of various indexes of service reliability for the purpose of choosing the one among them that seems preferable, and of recommending a level, or levels, of service reliability.

The load duration curve referred to is the one obtained on the basis of the daily maximum loads having 365 points per years and called "the daily maximum load duration curve." Contingency reserve, computed on the basis of this curve, must be checked for overhaul requirements. For all practical purposes it is simple and sufficient to add the overhaul requirements to the maximum daily loads. The load duration curve thus obtained is called the "daily maximum load-overhaul duration curve."

Three indexes of service reliability are, namely:

(*a*). Probability of loss of load—expressed as a fraction or as an expected frequency of one day loss of load every so many years.

(*b*). Expected energy loss, kilowatt-days or kilowatt-hours, per kilowatt of maximum load.

(*c*). Expected energy loss, kilowatt-days or kilowatt-hours, per kilowatt of installed capacity.

Expressions can be given for calculating these indexes in terms of the capacity outage probabilities, the reserve, and the "daily maximum load ratio." This is defined by the expression:

$$\frac{\text{sum of all daily maximum loads}}{365 \times \text{yearly maximum load}}$$

if the overhaul requirements are not added to the load; or by the expression:

$$\frac{\text{sum of all daily maximum loads plus overhaul requirements}}{365 \times \text{yearly maximum load plus overhaul at peak time}}$$

if the overhaul requirements are added to the load.

Key curves can be given from which, by appropriate replotting, probabilities of loss of load and energy loss expectancies may be obtained for any number of units and for any value of the daily maximum load ratio.

Which index of service reliability? Probability of loss of load is recommended in preference to energy loss expectancies.

Which level of service reliability? The answer to this question depends on local conditions. Voltage may be dropped under contingency to reduce load. Assuming a maximum voltage reduction of five per cent and, correspondingly, a five per cent drop in load, a level of service reliability, after voltage reduction, of one day loss of load expectancy for every 50 years is suggested. The expected frequency with which voltage will have to be dropped, within the five per cent limit, depends on the number of units, being the smaller—the smaller is the number of units. Tentatively, a drop of voltage expectancy, within the five per cent limit, of one day for every five years is recommended. Comments and suggestions from the industry are urged.

Probability methods, up to the present and in the knowledge of the author, have been used almost exclusively for determining absolute reserve requirements. The use of probability methods for the economic evaluation of alternative schemes of power supply is strongly recommended.

The Relation of Thermal Plant Design to Reserve Capacity Requirements; *M. J. Steinberg (Consolidated Edison Company of New York, Inc., New York, N. Y.).*

The current trend in thermal plant design is toward utilization of single turbogenerator for unit operation. This has been adopted in order to keep the unit investment per kilowatt of capacity added to a minimum where it is consistent with predicted operating economies. In general, the evaluation procedure involves a comparison of alternate designs and involves the determination of what differential investment can be justified by the operating savings. In so far as can be determined from available literature, little, if any, consideration is being given to the effect of plant design and in particular, the size and method of connection between boiler and turbogenerator units, on the reserve capacity requirements of the system of which the contemplated plant is but one of several sources of supply. The paper illustrates how system reserve requirements are affected by the size and arrangement of units in a plant with ultimate design capacity of 640,000 kw, and evaluates the differentials in capacity requirements for peak demand reserve and for scheduled outages during off-peak periods for overhaul of equipment. From a system view point, serious consideration should be given to the utilization of a common steam header as a means of connection between boiler and turbogenerator units; to the installation of a multiple number of boilers for each turbogenerator unit; and to the installation of boiler reserve above capacity requirements of the turbogenerators. The views expressed in the paper are pertinent to the current issue of whether or not the reheat cycle is economically justified since, for practical reasons, such installations are limited to the adoption of the single boiler, single turbogenerator design.

Undervoltage Protection of Motorized Devices; *W. R. Wiese (The Cincinnati Gas and Electric Company, Cincinnati, Ohio).*

Undervoltage protection devices for motorized equipment should be designed and applied so that maximum service continuity can be realized by the user. From the utilities standpoint, it is desirable to have motor drives "ride through" as many system disturbances as possible. In this way, it is possible to take full advantage of the "built-in" service reliability and service restoration features of the modern electric system.

The ratio of system disturbances caused by faults on the major transmission system to those on the distribution system will vary depending upon the size of the system, location of generating plants, preventive maintenance program, tree interference, line patrol, and other factors. The use of time delay must be evaluated according to the individual situations and conditions. Possibly, time delay is desirable in most instances but this should not preclude the availability of instantaneous devices or those without definite time delay.

Some of the major items to be evaluated and considered in the study of time delay versus instantaneous undervoltage protection are

1. No thermal damage to equipment can result if the equipment is properly fused or protected against overload and single-phase operation of polyphase motors.

2. Large motors may require special treatment depending upon application and under certain conditions will prevent rapid reclosure of transmision lines.

3. From the utility system standpoint it is generally desirable to keep residential, commercial, and small power loads running in order to avoid "pick-up" troubles and motor controls should be provided to allow the motor drives to "ride through" as many system disturbances as possible to take full advantage of the service restoration features of the electric system.

4. Ultrafast tripping and reclosing of circuits supplying steel mills would be required if any attempt is made to prevent shutdown and the time requirements less than "dead time" allowance in the reclosing cycle.

5. Utilities desire to provide service which best serves the customer against damage to equipment when abnormal conditions exist beyond their control.

Electrical Maintenance Problems in Continuous Process Plants; *T. O. Sweatt (Wearn, Vreeland, Carlson and Sweatt, Inc., New York, N. Y.).*

In recent years the rapidly increasing cost of labor has resulted in a renewed trend toward mechanization in industry. This has resulted in the adoption of continuous mass production methods in many industries which heretofore had operated entirely on a shift basis. Usually these processes have been installed in existing plants where the electric distribution systems were not designed to serve them adequately and still permit proper maintenance. In such a plant the problem resolves itself into providing sufficient duplicate service to all critical loads to permit adequate maintenance of each and every major component of the distribution system without affecting the over-all operation of the plant.

The first step in attacking the problem should be the tabulation of all present and contemplated loads as either essential, moderately essential, or nonessential. The

distribution system should then be carefully analyzed to segregate the essential and moderately essential loads from the non-essential wherever possible. This will materially reduce the extent of the changes required to the system.

It is extremely desirable that a reserve source of power be provided for the plant sufficient to supply the essential loads whenever the primary source of power is being maintained or repaired. If the primary source is a public utility, close collaboration with the utility engineers is essential. The primary substation supplying the plant really constitutes the heart of the distribution system. Unfortunately, most plants have only a single primary bus which generally cannot be properly maintained without shutting down the entire plant. Some means for sectionalizing the bus should be provided and also means for independently supplying each bus section from the power source.

Primary distribution systems in existing plants are generally of the simple radial type with the feeders and substations supplying loads on an area basis. Both continuity of service and maintenance requirements generally dictate the provision of duplicate supplies to all substations serving essential loads. The two basic methods commonly employed consist of either duplicate feeders or loop feeders using sectionalizing circuit breakers. Whichever method is used, the feeder arrangement should be such that all essential substations are supplied from two or more sources such as separate bus sections in the primary substation.

Secondary substations are generally of the single transformer type and provision of duplicate facilities is difficult to justify. However, the judicious use of secondary interconnections will permit adequate maintenance of this equipment. Whenever possible, secondary distribution centers should be so allocated that each essential load component will be served by a separate center. Normal maintenance of the centers can then be performed simultaneously with the maintenance of the associated process equipment.

Interior Wiring Design for Commercial Buildings; *Alexander C. Youngson (Rice and Youngson, New York, N. Y.).*

In the fall of 1946 the Committee on Industrial Power Systems organized the Subcommittee on Interior Wiring Design for Commercial Buildings. This committee was composed of representatives of consulting engineers, electrical contracting firms, electrical and communication utilities, manufacturers, insurance underwriters, and the Committee on Domestic and Commercial Applications.

The committee was given the assignment of making a thorough study of the essential features entering into the electric systems in modern commercial buildings and to present their findings in the form of a report, which was presented on October 17, 1949, at the AIEE Fall General Meeting held in Cincinnati, Ohio.

The report is not intended to be an electrical handbook explaining in detail how to design the various systems, although some original data not usually found in handbooks have been included. It is more in the nature of a check list to assist the young electrical designer in preparing his layouts, or as a reminder to the more experienced engineers to avoid overlooking some essential requirement for adequate and safe operation of the equipment.

Certain important features of the electrical design if overlooked or improperly treated may result in unnecessary limitations and inconveniences, as well as unsatisfactory performance of the illuminating and utilization equipment and of the communication and signaling facilities. The failure of the electric systems due to inadequate planning and insufficient anticipation of future needs, contribute materially to the premature obsolescence of the property.

Data are included showing methods for estimating quickly the anticipated lighting and power loads necessary for preliminary studies, and some original unit cost data which can be readily used for calculating the approximate cost of a system, or for comparing the costs of two or more systems of different design. Some unit data on telephone requirements and of space required for the equipment, are also included.

The classification of commercial buildings is very wide as used in utility practice, and some curtailment of the scope had to be adopted. In general all types of buildings have been included between the single and duplex residence and the industrial buildings, except farm, transportation, specialized municipal buildings, outdoor sports, special laboratories, also special and unusual buildings of all types.

The text covers the general electric, communication, and signaling systems usually found in modern buildings, also special electrical facilities required in each of the following types of buildings: office and lift buildings, municipal administrative buildings, banks, brokerage offices, hotels, apartment houses, clubs, restaurants, theaters, auditoriums, churches, recreational buildings, schools, colleges, libraries, museums, hospitals, clinics, medical and dental offices, department stores, merchandising and service establishments, and automotive garages.

Undervoltage Protection of Motorized Drives; *J. C. Lynch (Hammerhill Paper Company, Erie, Pa.).*

This paper notes the electric power and drive requirements of a 300-ton-per-day pulp and paper mill utilizing the sulphite process. Since the plant generates all of its power requirements, power generation and distribution facilities are described, primarily from a continuity of service point of view.

Paper-making is a continuous process and continuity of operation is of vital importance. However, if the process is divided into: wood handling and chip preparation; acid making and pulp cooking; pulp washing and bleaching; beating and paper machine operation; and finishing; we find these operations instantaneously independent of each other due to some measure of surge or storage capacity at the end of each operation.

Certain operations, notably in the acid making, pulp cooking, screening, and machining phases of paper-making are sufficiently important to justify an attempt to carry the drives through a momentary low-voltage condition or a feeder reclosing cycle. In these instances damage to equipment and poor quality of product are likely to result in the event of power failure.

In other operations, such as wood barking and chipping, beating, and refining, continuity of operation is desirable but not vital. In general, the characteristic of these loads is such that an attempt to carry the drives through a feeder reclosing cycle would result in severe overloading of feeders and unit substation transformer equipment.

The use of timed undervoltage protection devices is indicated where increased production, a better quality of product, or greater safety in operations will result. In cases where these qualifications do not necessarily apply, the extra duty imposed on the power system through the use of time delay undervoltage protection devices is not justified.

Phase Shifting 22-Kv Regulators Save System Investment; *V. E. Hill (Duquesne Light Company, Pittsburgh, Pa.).*

In the complex power system networks of today, the power does not always flow in the proper proportions over the paths available, owing to the location of the loads, length and characteristics of the transmission circuits, and the source of the power supply. Thus, while there may be ample line capacity, it cannot all be utilized, and the problem is to secure a more effective use of existing equipment.

Through the installation of two phase shifting regulators to a 22-kv network, the Duquesne Light Company has improved the distribution of power over existing circuits to the point where expensive new circuits were not needed. These regulators made it possible to carry a simultaneous load of 80 per cent of the sum of the ratings of four 22-kv lines supplied from three different power sources.

It will also be found that regulators of this type frequently have other advantages. They have permitted an increase in the maximum load capability (firm power rating) of bulk supply substations, and have also proved extremely useful in maintaining voltages, particularly during times of equipment outages due to trouble or maintenance. The gain in line loadings and bulk supply substation capacity of the first regulator was conservatively evaluated at $140,000 as against the installed regulator cost of $40,000.

The two regulators are exactly similar in principle, but have slightly different ratings: one is rated at 1,260 kva and ±10 per cent voltage control, and the other is rated at 2,040 kva, ±16 per cent voltage control. Load capability in both cases is about 12,500 kva. Phase angle adjustment of the ±10 per cent and the ±16 per cent voltage change can be set for 0 degrees, 30 degrees, 60 degrees, and 90 degrees by means of easily accessible no-load tap changers. Experience has demonstrated that setting the phase adjustment at one angle gives satisfactory control, and that taking the regulator out of service for a few minutes to change this adjustment has proved no hardship.

Spotting Equipment for Synchronous Motors; *S. C. Ewing, E. A. E. Rich (General Electric Company, Schenectady, N. Y.).*

"Spotting" as used here refers to the operation of accurately stopping rotating machines in a predetermined angular position. To do this, it is often necessary to rotate machines at speeds of approximately one per cent or less of normal rpm. Many mechanical and electrical methods of obtaining these ultra-slow speeds are available.

Most electrical methods of spotting synchronous motors consist of exciting the field poles from a constant excitation source and applying some form of, in effect, low-frequency power to the armature winding.

The method of obtaining low frequency in the motor armature winding which is used by the equipment described is several decades old and essentially consists of applying direct currents to three phases of the armature, using contactors, in such a way that an ultra-slow moving armature field results.

A major requirement of spotting equipment is that some means be provided to keep the spotting control equipment completely and positively isolated from the main a-c power supply. Hazards to equipment and life of personnel may arise if this problem is not given adequate consideration. A fairly reliable way of obtaining this isolating requirement is through the use of interlocked, magnetically operated, contactors or circuit breakers to provide means of isolation of the spotting equipment from the a-c power supply and to connect the spotting equipment to the synchronous motor armature winding.

The spotting control equipment includes additional relays and contactors necessary to apply the direct current in proper sequence and polarities to the armature winding of the synchronous motor and to provide reasonable protection to the motor windings during the spotting operation. The equipment described includes provision for spotting the synchronous motor in either direction of rotation and at adjustable speed levels, ranging from about one-fourth to three-fourths of one per cent of normal speed.

Most common applications of spotting equipment are found in connection with drives for tube mills, rolling mills, and so forth, which may require fixed angular positions to load, unload, lubricate, make repairs, adjustments, and to replace or change parts.

A Proposed Classification for Regulating Systems; *S. L. Burgwin* (*Westinghouse Electric Corporation, Buffalo, N. Y.*).

Closed loop feed-back systems are used in almost every control process. Many variations of closed loop systems are used. Terminology for describing the systems and analytical viewpoint are equally varied. A broad general classification of possible systems is a starting point toward standardization of terminology and viewpoint.

Closed loop systems can be classified according to

A. *Complexity*
1. Simple (single loop).
2. Complex (main loop with one or more minor loops).

B. *Continuity*
.1 Continuous.
.2 Discontinuous (off and on type).

C. *Order*
.01 Direct (no integrating or differentiating mechanism).
.02 Integral (one pure integrating mechanism).
.03 Bi-integral (two pure integrating mechanisms).
.04 Differential (one differentiating mechanism).
.05 Bidifferential (two differentiating mechanisms).

D. *Mode of Operation*
.001 Damped.
.002 Oscillatory.

Systems can be quite completely described by use of this classification. For example, a particular system could be a complex-continuous-integral-damped system or a simple-discontinuous-oscillatory system as the case might be.

Association of relative operating characteristics with the various classes permits a fair qualitative idea of comparative operation of the various systems. The classification, together with a chart of comparative operating characteristics, provides a good over-all view of possible systems for a given application.

Line Circuits for Centralized Traffic Control; *G. W. Baughman* (*Union Switch and Signal Company, Swissvale, Pa.*).

Centralized traffic control is being credited with having played a major part in expediting the very heavy railway traffic which existed during the recent war. This is a system of train operation where the trains are operated in accord with signal indications and it displaces the previous method which required "train orders" to be delivered to the various train crews. Experience has shown that a single-track railroad equipped with a centralized traffic control system will have approximately 80 per cent of the track capacity of a double-track road operated without centralized traffic control.

The basic principles were developed and a number of relatively small installations were placed in service during the late 20's and throughout the 30's. Codes are transmitted automatically over a 2-wire line circuit from the control point to the various stations along the railroad for the purpose of positioning the switches and signals in accord with the desire of the operator as expressed by him by the proper positioning of the control levers. Codes are transmitted from the various stations along the railroad to the control point over this same pair of line wires for the purpose of displaying information on the panel in front of the operator giving the location of all trains in the territory and the positions of all switches and signals. Safety and checking features are provided so the operator cannot set up unsafe conditions.

When it became necessary to find a prompt method for expediting the war traffic, centralized traffic control won over the other methods because it could be installed more promptly and with a lesser expenditure than would have been required for other methods. There was a sudden demand for installations much longer than had previously been placed in service. Because of the situation which existed at that time in regard to copper for line wire, it was necessary to economize to the greatest practical extent in the use of this critical material. Also, communication facilities were at a premium on the railroads during the period of heavy traffic. By novel design of the line circuit, it was found practical to connect the line relays at all field stations in multiple so there were no contacts or coils in series with the line wires. Then, by the use of a specially designed low-pass filter in each multiple tap to the line, a high-grade voice communication circuit was derived. Methods were also developed to permit the centralized traffic control system to be handled over existing dispatchers' lines and at the same time retain all of the normal facilities of the dispatchers' line.

Novel applications of filtering and electronic equipment permitted the lines of long installations to be divided into independent sections and all controlled from the headquarters location. Installations are now in service with as many as six independent sections and with a length as great as 410 miles from the control point to the most distant function. It is the present standard practice to use the one pair of wires for centralized traffic control, voice communication, and one or more carrier communication circuits, and in some instances still other facilities. There are at present 87 sections of centralized traffic control line being controlled from a remote location by electronic equipment.

The application of these principles has brought about the saving of thousands of miles of line wire which results in economy not only in first cost but in reduced maintenance charges.

Erie Railroad's 4-Way Train Radio System; *Francis H. Menagh* (*Erie Railroad Company, Cleveland, Ohio*).

Maintaining constant communication with trains operating in territories where main line tracks wind through irregular terrain and highly industrialized areas faced Erie Railroad and radio equipment technicians several years ago in their preliminary studies of the feasability of using radio in railroad operation. At the close of the last war, radio manufacturers brought out the first very-high-frequency equipment designed to meet the special rugged and static-free requirements of railroad operation. At the same time, improved types of inductive carrier equipment were made available and demonstration tests of both were offered to the railroads.

The Erie Railroad's approach in adapting them to its needs was probably typical. Operating between New York and Chicago, the Erie tracks thread through some of the most irregular terrain in the East for hundreds of miles to Marion, Ohio, from there west a plateau provides smooth rolling for the remaining distance. The seasons are filled with every kind of weather with the usual extremes of temperature found in the north.

The basic problem was to provide constant 4-way communication between head and rear ends of trains; between trains and fixed wayside stations; between trains operating within range; and between way stations in case of landline prostration.

The Erie's experiences with the latest in radio communication date back to 1945 when tests of inductive carrier and space radio equipments were conducted along the right of way. Tests were also made in the New York Harbor lighterage area, which resulted in the present communication between the tug dispatcher and all Erie tugs. In 1947, a very-high-frequency installation was made in the Jamestown, N. Y., freight yards to provide 2-way communication between a base station and the diesel switch engines. The system demonstrated radio's ability to improve efficiency and safety of operations in this industrial yard switching service.

In July 1948, after more than a year of testing to determine the most practicable system to meet Erie needs, the present 4-way radiotelephone system was installed over three divisions. Within a year, its success was demonstrated and expansion was ordered to cover the entire 884 mile area west from New York, approximately 85 per cent of the main line.

The Erie very-high-frequency radio system

utilizes a series of base stations, operating at 160.05 megacycles, and a transmitter receiver in both cabs of diesel-electric road locomotives and 35 cabooses. When completed, there will be a total of 93 mobile stations and 50 way or base stations. Normal communication is on the *A* band of 160.05 megacycles with a *B* band of 159.09 megacycles available when *A* band is in use. When the *B* band is used, return of the handset to its hook automatically returns the mobile station to the normal frequency of 160.05 megacycles.

The base stations are located along the right of way to provide continuous communication between trains within range and between adjacent base stations. The most efficient site for the base station rarely coincides with the 24-hour wayside office from which it is controlled. As a result, several of the base stations are remotely controlled from a 24-hour office, and some, up to 28 miles distant, are similarly controlled over specially developed carrier apparatus operating at 175 kc, superimposed on existing wires.

In the way station, the control console is located on a desk with push-to-talk button in the handset. The console unit makes use of a low-voltage low-frequency tone, produced when the press switch is operated. The tone is transferred by wire to another control unit at the transmitter site, either at or remote from the control point. This second control unit takes the incoming tone to energize the transmitter; to send back a d-c simplex voltage to give the user at the control point a visual indication that plate voltage is one; to simultaneously disconnect the receiver and connect the transmitter to antenna; and to reverse the process to a normal standby condition when the tone is no longer received.

All units are automatic plug-in, unitized construction type and are serviced at maintenance depots at Marion and Hornell. Since all main-line diesel power is operating through these two points, opportunity is offered to inspect regularly all mobile radio equipment.

When failures occur, the maintainer replaces the unit with a spare and ships the defective equipment to the Marion shop where a Federal Communications Commission licensed radio technician makes all transmitter adjustments.

Maintenance of the caboose axle-driven generators and converters on all mobile installations is performed by the mechanical department's electrical section which is also located at Marion.

The principal radio system is utilized to control nine diesel switching locomotives in the Marion classification yard and industrial area. These locomotives communicate on *B* band with the Marion base station which employs a convenient floodlight tower to support its antenna. Main-line mobile stations contact the Marion station by using their *B* frequency and the base reverses the procedure by switching to the *A* band, the normal operating frequency on the main line.

Before next February, the Erie expects to equip with radio 34 smaller passenger, freight, and switcher-type diesel locomotives in Eastern District service. In addition, it faces a tremendous task of substituting three new frequencies for those now used in main line, New York Harbor service, and yards by order of the Federal Communications Commission before February 1, 1950.

When the Erie completes its 4-way radio communications system, as discussed, it will have what is believed to be the most extensive and comprehensive main line installation of any railroad in the United States.

Communications System on the Sante Fe Railroad; *L. R. Thomas* (*Atchison, Topeka and Santa Fe Railway Company, Chicago, Ill.*).

The Santa Fe Railroad operates 13,107 route miles of track in 12 states and has established one of the largest and most modern privately owned communications systems in the world today. This system will consist of the following fundamental circuits:

Local Morse telegraph circuits for handling of message traffic between small stations and from small stations to division relay offices.

Local conversation telephone circuits for handling telephone communications between local way stations and between local way stations and division offices.

Dispatcher telephone circuits for the handling of communication traffic in regards to the movement of trains.

Trunk telegraph circuits which normally use printing telegraph equipment for handling message traffic between larger offices.

Trunk telephone circuits for long line communication.

The Santa Fe's communications system made up of the afore-mentioned circuits consists of 13,984 miles of pole line carrying 87,322 miles of physical telegraph and telephone circuits over which 24,075 miles of telephone carrier and 59,029 miles of telegraph carrier circuits operate. These circuits carry a traffic load of over 36,400,000 telegrams and telegraphic reports and approximately 11,200,000 telephone calls annually.

Drawn and Extruded Aluminum Products in Relation to the Electrical Industry; *H. V. Menking* (*Reynolds Metal Company, Louisville, Ky.*).

Drawn and extruded aluminum products comprise: drawn wire and cable, drawn tubing; extruded tubing; extruded rod, bar, and shapes. The combination of low cost and favorable properties (notably, high electrical conductivity, light weight, good resistance to corrosion, high strength, and ease of fabrication) has led to the use of drawn and extruded aluminum products in many fields of the electrical industry.

Extruded bus conductors and steel-reinforced transmission cable stranded from aluminum wire are lighter than copper conductors, hence, permit economies through greater span lengths. Insulated aluminum wire and cable is employed in many industrial plants.

Inasmuch as the conductivity of aluminum is lower than that of copper, cross sections must be increased from 27 to 64 per cent, depending upon applicable standards. However, since the weight of aluminum is less than one-third that of copper, weight savings of 50 per cent or more are normally experienced in spite of the larger area.

Aluminum-to-aluminum connections in conductors are made by argon-arc welding; mechanical joints such as compression sleeves or bolting, using special petrolatum-base joint compounds or silver plating to maintain low contact resistance; or soft soldering.

Aluminum is joined to copper by flash-butt welding; mechanically (the copper part is cadmium-plated to prevent galvanic corrosion; joint compounds are desirable); wafer-type bimetallic plates of aluminum and copper, joined by soft soldering (sweating). The choice of joining methods for aluminum to aluminum or to copper depends on the application.

Substations and transmission towers built of aluminum shapes and tubing are easily erected, require no painting. Aluminum sheathing for cable, replacing lead sheathing, permits great weight reduction. Aluminum conduit is used in many applications where lightness, corrosion resistance, or nonmagnetic properties are desired.

The possibilities of aluminum magnet wire in motors and of aluminum rotor windings in turbogenerators are being investigated. Some current-carrying switch parts made of extruded aluminum, replacing bronze, eliminate "bouncing." Some conductor rails in crane and hoist equipment are extruded of aluminum.

In communication equipment, the good shielding characteristics and the light weight of aluminum are desirable. Aluminum lamp posts are used on highway bridges. Good brazing characteristics, high thermal conductivity, immunity to rust, and ease of fabrication are the factors responsible for many uses of aluminum in electric household appliances.

Analysis of Power Costs of Bituminous Coal Mines; *H. P. Musser* (*West Virginia Engineering Company, Charleston, W. Va.*).

The trends and amount of electric power use and cost at bituminous coal mines are of interest to the engineer, the executive, and the operating man alike. In determining these trends, a study of the data based on a single year, or even a few years, could result in misleading conclusions; but using the data from over 400 representative mines for the past 26 years makes it possible to determine the trends quite accurately.

The history of electricity as applied to bituminous coal mining has been one of growing use of inexpensive electric power to replace increasingly expensive labor. This is natural and proper, and has been accomplished by the mechanization of the mines.

This study of the use of electricity began in 1918 with a yearly analysis of power use and cost for a large group of mines having widely varying physical conditions and tonnage output. By 1923 the items of data collected had become stabilized and comparable data could be collected each year. For 31 years this analysis has been made, each year covering over 400 mines, principally in West Virginia, Virginia, Kentucky, Tennessee, and Pennsylvania, with a few in Ohio and Maryland.

In 1923 there were 18 per cent of the coal companies included in the analysis, operating their own generating plants; whereas, in 1948 this percentage had dwindled to 1.1 per cent. The large central station generating plants have been able to generate and sell power at steadily decreasing costs, while the private plant has been handicapped by steadily increasing labor costs.

A study of the record of the average mine in each tonnage class, for each year from 1923 to 1948 shows:

1. *Kilowatt-hours required per ton mined.* With each succeeding year more electricity is required for each ton

of coal mined. The percentage of coal loaded mechanically is increasing rapidly, being approximately 40 per cent in 1944, and 60 per cent in 1948 for the group of mines included in this study.

2. *Cost of units of electricity.* The total cost of a unit of electricity (kilowatt-hour) purchased by the mines, shows a steady and definite decreasing trend. This trend may be attributed to rate reductions, bettering the load factors, and particularly to the increasing use of kilowatt-hours in the lower priced brackets of the energy scale.

3. *Power costs per ton of coal mined.* The net result of progressively lower costs per kilowatt-hour purchased and of increased amounts of electricity used in mining each ton of coal, has been an almost constant cost of power per ton of coal mined, over the period from 1923 to 1942. Since 1942 there has been an upward trend due to inflationary conditions.

4. *Load factor of power purchases.* In general, all the groups of mines have succeeded in improving the load factor of their purchases. The large mines are able to maintain the best load factors, due to greater diversity of their many power requirements. This is one of the main reasons why power costs are proportionally less to the large tonnage mines.

To summarize, the data for the last 26 years clearly show the increasing use of electricity in bituminous coal mining, brought about chiefly by increased mechanization; the decreased cost of electricity per kilowatt-hour, the result of both these trends being a practically constant cost per ton for power. Also, the continued trend away from private steam plants to central station power is quite pronounced.

The Transition Air Navigation System and Its Evolution; *S. A. Mundell* (*Air Force Member, Air Navigation Development Board*).

Starting with the present 4-course radio-range system operating at 200 to 400 kc, the paper describes the evolution of a new system of air navigation and traffic control which is now coming into operation. The present system is limited in that only four courses are furnished and also in that the frequency range suffers from atmospherics and precipitation static. The new system includes beacons operating in the very-high-frequency range from 108 to 118 megacycles and having an omnidirectional feature.

Another feature of the new system is the inclusion of distance-measuring equipment, by which the pilot or navigator is furnished his distance from known points at all times, as distinct from occasional checks afforded by the present facilities. By adding a computer to the equipment on the airplane, the craft is furnished continuous data on distance and direction with respect to any desired way point or destination different from the location of the nearest beacon.

Improved control of aircraft on the airways will result from more reliable data being in possession of the pilot and being reported to ground. In addition, radar will be used for traffic control in terminal areas. Among the equipment yet to be developed is that for automatically communicating to ground the identity of an airplane its altitude, and other data.

Progress on the new system of aids has been made to the extent that 200 very-high-frequency omnidirectional range stations out of a total of 409 have been commissioned. Development of the distance-measuring equipment is proceeding rapidly and it is hoped that procurement and installation will take place within the next year. Specifications for the computer are being written, which should provide that equipment in the near future. The Civil Aeronautics Administration, the Air Force, and the Navy have installed and are continuing the installation of instrument landing systems (ILS) and ground control approach (GCA) at many airports. All three agencies are obtaining and installing radars at airports with heavy traffic.

Technical Features of Air-borne and Ground Distance Measuring Equipment; *Charles J. Hirsch, R. B. Brunn, H. Blaisdell* (*Hazeltine Electronics Corporation, Little Neck, N. Y.*).

Distance measuring equipment (DME) has been internationally adopted as a radio aid to aviation for short-distance navigation. The equipment consists essentially of a pulse-type secondary radar comprising an air-borne interrogator-responser and a ground-station transpondor beacon. The air-borne unit finds its distance from the beacon and furnishes that information automatically as a voltage or shaft rotation which can be read on a meter and can be used to actuate a computer and an automatic pilot.

The system has been standardized to give the distance to any one of 100 ground beacons. These channels are obtained by a combination of paired-pulse coding and frequency selection. In paired-pulse coding each signal consists of two pulses whose time separation is characteristic of the particular signal. Each of the 100 interrogation paths (airplane to ground) consists of a combination of one of 10 frequencies lying between 963.5 and 986 megacycles and one of 10 interrogation codes having spacings between 14 and 77 microseconds. Each of the 100 reply paths (ground to airplane) consists of a combination of one of 10 frequencies lying between 1,188.5 and 1,211 megacycles and one of 10 reply codes which, like the interrogation codes, have spacings between 14 and 77 microseconds. No two beacons have the same combination of interrogation and reply frequencies, so that both frequency and code discrimination are always utilized.

In the design special attention was paid to the radio-frequency power output, receiver sensitivity, frequency stability, and selectivity. Usual types of tuned circuits have less selectivity with pulse signals than with continuous wave signals. This is because pulses have extended frequency spectra. New circuits are employed which make the selectivity of the equipment for pulse signals at least equal to, and in some cases superior to, the selectivity for continuous wave signals. Circuits which generate and recognize paired pulses of characteristic spacing are used. These circuits operate even though random pulses occur between the two pulses of a single pair.

The number of airplanes that can be handled by this system is determined by the ratio of wanted signals actually recognized by the air-borne equipment to unwanted signals. Some unwanted pulse pairs on a common frequency are received in such a time sequence as to have the time-spacing characteristic of the desired signal. These pseudo-signals increase the apparent number of airplanes and beacons and thereby lower the total traffic-handling capacity. Curves of this effect demonstrate that the system is well capable of handling the maximum traffic which has been contemplated by the Civil Aeronautics Administration for the next 15 years.

The Application of the Rototrol Rotating Regulator to Machine Tools; *M. H. Fisher* (*Westinghouse Electric Corporation, East Pittsburgh, Pa.*).

The ultimate in machine tool drives is one that provides exact speeds for best cutting and maximum output. It is desirable that this drive have the features of constant speed with varying load, remote and stepless speed adjustment and speed change while the machine is running, as well as economy and ease of maintenance.

The use of adjustable speed electric equipment has allowed the machine tool manufacturer to eliminate expensive gear boxes and obtain better means for driving machine tools with simple control, increase speed range, and more accurate speed of operation. The Rototrol Rotating Regulator has contributed much toward meeting the machine tool builder's requirements for a speed-regulated adjustable-speed drive.

Fundamentally the Rototrol is similar in design and theory of operation to a standard d-c generator, but is operated on the straight portion of the saturation curve and has a number of field windings which are connected in various ways in the electric circuit depending on the regulating problem. It functions entirely through the interaction of these fields.

The most popular Rototrol regulated machine tool drive uses a counter electromotive force speed regulator. The fields on the power supply generator are arranged in two parallel legs of a bridge circuit with resistors in the other two legs and the bridge circuit is excited at two terminals from the exciter. Regulating power is supplied to the generator field by a Rototrol connected to the other two terminals of the bridge circuit. Approximately 1,350 of these drives ranging from 10 to 100 horsepower in size and designed to operate over a 30-to-1 speed range (40 to 1,200 rpm) have been sold to date.

Although the Rototrol has been applied to machine tools most actively as a speed regulator, a special Rototrol Rotating Regulator of the current limit type has been applied to dynetric balancing machines. In the dynetric balancing machine, the current limit Rototrol effectively limits the accelerating and decelerating torque transmitted through a delicate coupling located between the drive motor and the mass to be balanced to the maximum safe value which can be transmitted through the coupling without damage.

Although the Rototrol can be used for the regulation of voltage, current, speed, torque, tension, and numerous other quantities which can be measured electrically, the applications mentioned represent only two of these many functions. Perhaps with the right application of the ingenuity which exists in the machine tool industry, more active use of the Rototrol to control other quantities can be developed.

Electronic Control as Applied to Grinders; *J. M. Morgan, Jr.* (*Cincinnati Milling Machine Company, Cincinnati, Ohio*).

Large precision grinding machines are a typical example of a machine tool requiring, along with many other features, a wide speed range drive. As engineered and manufactured by the Cincinnati Milling Machine Company, and with the proper application of a standard electronic motor drive, these machines illustrate the flexibility, reliability,

and accurate speed control that are inherent characteristics of electronic control.

The paper describes the requirements of a cable drive on a precision grinding machine, and how by proper design and application of both mechanical and electrical components the various problems encountered have been solved. The electronic motor control has not been described, except where required for clairty, since it has been thoroughly covered by previous papers.

The requirements for a precision grinding machine table drive are wide speed range, ample starting torque, accurate speed control, freedom from vibration, simple, convenient operation, smooth acceleration and deceleration, and adjustable tarry time at each end of travel. Many of these features are a basic part of electronic motor control. Others require additional mechanical and electrical control.

The electronic table drive can be considered as being made up of several component circuits, which are an electronic motor drive, reversing control, starting control, slowdown control, and adjustable tarry time control.

The electronic table drive provides a wide range speed control that is reliable, easy to operate, and economical. As used on large precision grinding machines, it illustrates the flexibility that can be easily obtained with this type of control. In addition, it shows how a standard commercial product can be used on a standard machine tool by proper application and engineering.

Electrical Control of Belt Conveyors; *W. F. Roberts* (*The Jeffrey Manufacturing Company, Columbus, Ohio*).

Belt conveyors, for coal mine use, have developed into various combinations of tandem and cross conveyors serving, in many instances, a square mile or more of territory. For economic reasons an operator cannot be stationed at the control unit of each individual conveyor to start or stop it at the proper time. The usual practice is to have only one operator who is located at the discharge end of the system to supervise the flow of coal.

Thus an interlocked sequence control arrangement is necessary properly to start or stop the system of conveyors from one or more places. Control should provide for starting the outby conveyor first and inby conveyors in sequence in such manner that no conveyor can start until its receiving conveyor has first started. Provision should also be made to prevent piling up of coal at transfer points. For safety it should be possible to stop the belt from any point along its length.

Impracticability of having close supervision over the thousands of feet of conveyor length makes it essential to have automatic protection against damage to the expensive belting. As an example if a belt splice orbelt tension device should fail, the belt would stop but the motor would continue running. Friction between lagged drive pulleys and stationary belt could act the belt on fire with the possibility of a bad mine fire and it could cause burnt-out lagging and ruined bearings.

The control should be arranged to stop the motor if the belt separates or stops because of jamming of coal against roof or loss of tension.

Where cross conveyors discharge on to main belts, with no operator at this point, it is desirable to have automatic surge protection to prevent spillage. When the main conveyor is loaded to capacity, the cross conveyor should shut down and should restart, automatically, when the load on the main belt becomes normal.

Finally, when shuttle cars discharge on a belt conveyor it is advantageous to have a high belt speed (about 500 feet per minute) during the unloading period so the shuttle car can unload quickly. At other times half speed is desirable for safety when carrying men or supplies or for less maintenance cost.

Two-speed control can be provided to suit these conditions.

Preliminary Report on Survey of Operation of Mercury Arc Rectifiers; *W. N. Farquhar* (*Aluminum Company of America, Pittsburgh, Pa.*).

Early this year the Application Subcommittee of the Committee on Electronic Power Conventions prepared a questionnaire which was sent to all users of mercury arc rectifiers in America. Since requirements of various applications differ, the users were divided into the following three classifications:

1. Electrochemical service.
2. Railway transportation service.
3. Mining, steel, and industrial service.

Basically the questionnaires for each classification were the same; however, due to variations in service requirements, the details of a portion of the questionnaires differed to conform with the type of service. The major items included in the survey were: number of units, unit capacity, type of rectifier and switchgear, a-c supply, and direct voltage, cooling, operating, and maintenance man-hour requirements, types of troubles, and spare part requirements.

Questionnaires were sent to a total of 656 users of which 80 per cent were in the mining, steel, and industrial classification, and 10 per cent each in the other two. Approximately 25 per cent of the questionnaries sent out have been returned to date.

The sponsoring committee believes that the survey results will be of benefit to both users and manufacturers by providing a comprehensive source of operating experience and indicating where design improvements are most desirable. Also, the survey results could be used to develop a standard log or record form which would help users to standardize operating and maintenance records.

Automatic Programming of Machine Cycles; *R. N. Eck* (*Cutler-Hammer, Inc., Milwaukee, Wis.*).

Programming is herein used to denote the setting up of a series of machine operations which will take place automatically. Flexibility, or ease in changing from one program to another, is particularly to be stressed.

One means of program selection is based upon the operation of limit switches in the proper sequence. For example, in a turret lathe a limit switch can be operated in each position of the turret for the purpose of selecting a different work speed for each turret face. The work speeds can then be preset to the desired values and the machine will change automatically.

This system of control can be expanded to apply to other machines and to include a selection of the function desired. The limit switch used to select the first operation desired makes a circuit to a number of selector switches, the position of which sets up the operation. As this operation progresses, another limit switch is operated to set up the second operation in a like manner. The complete machine opration is thereby controlled with great flexibility of setup.

In many instances it is not convenient to use a series of limit switches to control the machine sequence. Here a stepping-type relay might be used. This relay is stepped by electric impulses so that it makes a series of electric circuits in sequence. At the end of the operation it can be electrically reset to its starting position.

An application of this relay to the control of a machine program is found in a certain internal thread grinder. In this machine it is necessary automatically to reform or true the grinding wheel during the grinding cycle. A series of selector switches on the control panel provides a simple, flexible means of obtaining grinding passes and truing operations in any sequence desired up to a maximum total of 15 operations. More selector switches combined with more steps on the relay could provide a higher total if desired. Once the setup man has determined the manner of grinding a given piece of work, the production will be accurately maintained.

Counters and timers can also be used to control machine programs.

Cable Reel for Use On Mine Locomotives; *J. R. Doig* (*General Electric Company, Erie, Pa.*).

The first electric mine locomotive was operated by the Lykens Valley Colliery of the Pennsylvania Railroad in 1887, about five years ahead of the first trolley car. In 1902 a mechanical cable reel was developed and the room gathering locomotive came into use for handling empty and loaded coal cars to and from the room face. This reel was merely a device for automatically extending the trolley wire about 500 feet from any point. The first application was in the Cayuga Mine of what is now the Glen Alden Coal Company at Scranton, Pa.

The cable reel was motorized in 1908 using a small geared motor with a resistor in series. This improved reeling characteristics and had less maintenance.

In 1930 at the New Orient Mine of Chicago, Wilmington, and Franklin Coal Company a scheme of controlling the reel motor torque was applied automatically to insure adequate reeling-in pull and low unwinding pull on the reel cable. Contacts were added to the reverse cylinder of the controller for regulating the amount of series resistance in the cable reel motor circuit.

An automatic transfer switch made up of contactor units with holding coils connected from power source to ground through crossed interlocks, took the place of the early hand transfer switch for changing between cable reel and trolley power. Mine safety rules forced the development of this 100 per cent safe device.

At one time double conductor reel cable was common in nongaseous mines, the second conductor being used to supplement the rail return conductor, being grounded on the locomotive. On modern sealed-equipped locomotives for use in gaseous mines the second conductor has its own collector ring, the locomotive operating on metallic circuit from cable reel to insure against sparking at the rail.

Cable reel operation has become so success-

ful and so fast as to force the use of a single handle plugging controller to take advantage of it. This is a part of the easy, fast, and accurate operation necessary behind a loading machine.

Cable used on a 24-inch diameter vertical axis drum reels automatically on 8 inches of height with a 58 per cent space factor. Concentric double conductor cable winds better and is safer to handle than the flat duplex type, but is not so easy to splice when cut. Maximum cable size used is number 2 on 250-volt systems.

Power required to operate an electric cable reel averages 25 kilowatt-hours for a 7-hour shift.

Trolley Phone Mine Communication; *W. P. Place* (*Farmers Engineering and Manufacturing Company, Pittsburgh, Pa.*).

Carrier current underground to provide communication between fixed points and moving locomotives presented a number of special problems. Commutator ripple, uncertain contact of trolley shoes and wheels on sanded rails, and ignitron rectifiers cause an unusual amount of interference. The trolley system has many branches and many different loads which impair its effectiveness as a transmission line. Voltage variations, mechanical shock, heat, and dampness also need to be considered. These problems had to be solved either partially or completely to make up a workable system.

The high noise level makes a high gain in the receiver unnecessary, but a squelch circuit had to be used that would weigh noise against signal over wide limits. The reactance tube in the transmitter is stabilized to keep frequency drift within bounds even with widely varying plate and heater voltage, and the equipment is compact as possible because of space limitations. All parts need to be well anchored and the transreceiver cushioned on rubber to take care of shock and vibration.

All equipment, transreceiver, speaker, microphone, and so forth, must be able to withstand water dripping from the roof of damp mines and also rain where part of the haulage is above ground.

Liberal use of baking varnish and wax is needed to eliminate internal moisture troubles caused by high humidity in the summertime brought about by large amounts of outside air blown through the mine.

Transients from ignitron rectifiers often need to be filtered and sometimes a few motors need the same treatment. Parallel circuits, such as existing telephone lines, sometimes support the signal normally carried by the trolley. In many cases the coverage has been extended to seven or eight miles by coupling the trolley to the telephone line by means of impedance matching high-frequency transformers.

Noise produced by locomotives pulling cars requires the use of close talking microphones and sharp loud-speakers. Carbon microphones and re-entrant type loud-speakers have proved satisfactory.

The best frequencies to use seem to lie in the 30- to 100-kc range with no one frequency being outstandingly better than any other.

Enabling all motormen to talk to any and all others as well as to the dispatcher by means of this common talking press-to-talk system has resulted in gains in both efficiency and safety far above what might have been anticipated.

Motor Ripple Voltage and Its Application to Plugging Relays; *S. Noodleman* (*Standard Dayton Corporation, Dayton, Ohio*).

Motor ripple voltage is defined as the voltage generated in the windings of a squirrel-cage induction motor by the flux of the rotor teeth and rotation of the rotor. Thus, its frequency is the product of the number of rotor teeth and the rotor speed. The characteristics of this voltage are described for variations in input voltage, motor air gap, and rotor resistance. The data show that motor ripple voltage, both in magnitude and frequency, serves as an accurate reference of rotor speed and may be suitable for many applications which require the use of motor speed for control purposes.

One method of bringing induction motors to a rapid stop is by plugging. This method applies voltage of reverse phase to the motor, so that the motor rapidly decelerates, power being removed from the motor the instant the motor is at zero speed. The conventional control for this purpose is the "zero speed switch." This device is mechanically coupled to the motor and serves to drop out the starter at the proper speed to bring the motor to rest.

The plugging relays discussed in this report connect to the windings of the motor and utilize the ripple voltage generated by the rotor to control the starter in the same manner as the zero speed switch. They require no mechanical connections to the motor and may be panel-mounted and protected from the dust, dirt, oil, and vibration usually encountered by zero speed switches in the field. Their application to machine tools and other industrial equipment is described, as well as the inherent differences between these types of relays and the conventional type of mechanically operated switches.

A squirrel-cage induction motor is described which, while having the usual performance characteristics of a standard induction motor, also supplies at its terminals relatively large amounts of ripple voltage without the usual line frequency voltage which is normally present in the windings of conventional-type motors. This ripple voltage may be used for control without filters or other attenuation networks.

The use of this type of motor is described in position-stop systems, as well as other systems where a very accurate degree of control is desired in order to bring the machine to a precise stop. Tests show that the maximum errors which occur with this system of control are due to the time delays which occur in the magnetic starters and the variations in their operation.

This type of motor, when manufactured in the subfractional sizes, may be used directly as a tachometer by coupling it to the rotating member and feeding the generated ripple voltage into a switch voltmeter. A unique type of timer is also available through the use of the ripple voltage generated by these motors in combination with a series of relays, since a precise interval of time is required to plug these motors from idle speed to any given lower speed. The use of these types of motors for servo control is also indicated, since an accurate speed reference may be obtained for feed-back purposes.

What the Automotive Industry Expects of Electric Equipment on Machine Tools; *W. B. Nichol* (*Chevrolet Division of General Motors Corporation, Detroit, Mich.*).

What does the automobile industry expect of electric equipment on machine tools? The automobile industry expects of electric equipment on machine tools nothing more than one is entitled to expect of the electric and mechanical equipment on an automobile, namely, the assurance that the machine will be capable of performing dependably and with a minimum of maintenance interruption the job for which it was designed, from the day it is delivered until it is retired. To achieve this purpose the "Joint Industry Committee Electrical Standards for Industrial Equipment" have been written by an interested group of engineers.

It must be recognized that this or any other standard can be no substitute for knowledge of the job requirement. In some instances the size or apparent inflexibility of some of the automotive user plants has complicated a situation where the standard has been specified but the opportunity to explore and straighten out a difference of opinion between the vendor and the user has been denied.

The big problem has always been to get equipment which is rugged enough for the type of service, so placed as not be subjected to needless hazards, and accessible enough that it can be repaired easily, quickly, and with a minimum of waste motion. The standards call for no frills, but they permit of no skimping either. The simplest effective solution is the one which is wanted.

To amplify further the initial question concerning what the automobile industry expects of electric equipment on machine tools, one must look at how the automobile industry uses machine tools nowadays. The tools are placed in close proximity to each other to permit the work to be passed from one operation to the next with no waste motions. This means in many instances that a dry boring machine may be adjacent to a wet grinder which on occasion splashes coolant onto the former. Or perhaps a broach is so close to a dry grinder that the electric equipment of both are subject to the metallic dust which inevitably gets away from the latter no matter how much effort is made to prevent it. On the other hand, one machine may be placed where it creates no operating hazard for its neighbor, but does interfere with its maintenance if everything is not properly located. The things which are demanded are controls and wiring installations which will resist the type of hazard just described and when there is a breakdown, will permit it to be repaired easily and quickly.

It is hoped that ultimately the automobile industry can be assured that the machine tool they buy "off the shelf" will be as safe, rugged, and as easily repaired (yet with a minimum stock of repair parts) as though the job were customer-specified. Pleasing appearance, while no doubt desirable if possible without hampering the utility, is definitely an unimportant consideration.

General Principles of Applying Clutches and Brakes to Machine Tools; *Glenn A. Spohn* (*Gregg and Spohn, Cincinnati, Ohio*).

Clutches and brakes are in general use on machine tools to control the output speed of

the driven member. In selecting a unit some of the important problems are

1. Speed of start or stop.
2. Machine shock.
3. Heat.
4. Life.
5. Ease of torque adjustment.
6. Simplicity, ease of maintenance, reliability.
7. Design engineering.
8. Cost.

1. Will it start and stop the machine quickly enough?

The time (in seconds) to start or stop is equal to $\frac{(WR^2)\ (RPM)}{308\ T}$

WR^2 is inertia in pounds feet squared of the driven member

RPM is revolutions per minute change of speed

T is average torque exerted in pounds feet

The foregoing formula disregards the friction load. Knowing the duty cycle necessary, the designer can calculate or estimate the WR^2 of the members and can calculate the average torque required to perform the operation.

2. Will it shock the machine too much? The amount of shock will vary from practically zero for low gear speeds (as during starting) even though the average torque during the interval is high, to a maximum during the stopping cycle from high gear speeds if the stopping torque is applied suddenly at the same values. This would help to explain why it is possible to start a gear train by starting the driving motor at full voltage without noticeable shock, but when applying the same type of stopping torque by plugging the motor the shock is excessive. This has necessitated the use of reduced voltage plugging controls in many cases, and this becomes expensive, difficult to adjust the torque in the field, and limits the available torque to the allowable shock values.

For quick, shockless changing of speeds it is preferable that the application of torque be started at zero and then built up to its maximum value in a period of time along enough to take out all of the backlash on the system. This is a characteristic of a unit which has a comparatively high inductance (moment of inertia), is excited by direct current, and always delivers torque in some proportion to its magnetic flux. The backlash of the system is then taken up as the torque is gradually, although rapidly, increased and there is no appreciable difference in speeds at the time of impact.

3 and 4. Will it get too hot? Will it have reasonable life? The proper selection of the unit depends upon the inertia of the members to be controlled, the rate of applications per minute, the allowable time of operation, and the type of load on the driven members. All these factors contribute to heating, and heat dissipation is one of the most important factors in successful operation of the unit. This becomes all the more apparent when we consider that the energy to be dissipated in heat is equal to the energy change in the system (neglecting the effects of friction) per start or stop.

5. Can it be easily adjusted to the proper value or torque? Any device that can easily be adjusted in the field may save trouble calls and assure customer satisfaction.

6. Is it simple, easy to maintain, reliable? Reliability, simplicity, and lack of maintenance obviously would be extremely advantageous.

7. Is it easily engineered into design? The members should be as complete as possible in themselves, compact, and have minimum mechanical adjustments.

8. Will it cost too much? Any device that will cost money to install in the machine must justify itself either in increased production, ease of operation of the machine, safety, or in some other way. At a normal cost of operation of $5 an hour, or $10,000 a year, an increased production of even five per cent would amount to $500, thus the savings accruing from use of any combination of clutches or brakes can be evaluated in terms of dollars, and such information is sometimes the deciding factor in the purchase of a machine.

A New Control for Direct Drive Presses; *W. E. Large (Westinghouse Electric Corporation, Cheektowaga, N. Y.).*

Some 15 years ago it was found that a very satisfactory power switch for alternating current could be obtained by using ignitrons connected in "inverse parallel," or, as it is spoken of more often, "back to back." The widest application for this scheme has been in resistance welding. Years of experience on thousands of resistance welding jobs has proved that the ignitron contactor can successfully replace magnetic contactors, particularly in the switching of heavy power currents. When the currents exceed 150 amperes, magnetic contactors will not stand up under severe repetitive service.

The similarity of switching in resistance welding to that required for the larger direct-drive presses naturally suggested consideration of ignitron power switching. The maintenance of magnetic contactors operating many times per minute and breaking currents of thousands of amperes can be very costly, not only in replacement parts and the labor to install them, but in shutdown time of the apparatus being controlled. Replacement of magnetic contactors with ignitron contactors will take advantage of the silent, undemonstrative operating characteristics of the ignitron to control the heavy currents as fast and often as required. Elimination of moving parts will reduce the maintenance requirements to a minimum. Shutdown time will also be drastically reduced, for the trouble-free operating life of ignitrons can be measured in years.

A secondary advantage to be gained from the use of ignitron contactors stems from the ability to control the firing point of the ignitron during the voltage cycle. The correct starting point to obtain minimum current transients or surges can be precisely determined, and will be accurately repeated on every start. The closing point of magnetic contactors is a random affair, and the worst starting transients will be produced sometime during repetitive operation. The elimination of these transients will result in more stable line conditions, and reduced mechanical shock to the motor.

INSTITUTE ACTIVITIES

AIEE Winter General Meeting Again Scheduled for Hotel Statler in 1950

Inasmuch as last year's meeting was so successful, the AIEE Winter General Meeting will again be held in the Hotel Statler in New York, N. Y., during the week of January 30 through February 3, 1950. This change from the Engineering Societies Building to the Hotel Statler was made to provide more adequate meeting space and room facilities for scheduling committee meetings. The choice of the Hotel Statler will also prove advantageous to those out-of-town members who are in a position to use the Pennsylvania Railroad, as the Pennsylvania Station is adjacent to the headquarters hotel and connected to it by means of an underground passageway.

An extensive technical program is now in the course of development. The technical committees have shown an early interest in this winter's general meeting, as evidenced by the large number of technical sessions already requested. An incomplete tally shows 53 sessions scheduled.

ENTERTAINMENT

The highlights of the evening entertainment program include the smoker at the Hotel Commodore on Tuesday, January 31, and also the very popular dinner–dance which will be held on Thursday evening, February 2, at 7:30 p.m., in the main ballroom of the Hotel Statler, the center of all meeting activities. Formal dress is requested. More than 350 persons attended the affair last year and enjoyed an evening of good food, pleasant conversation, and general sociability. A popular innovation begun last year will be repeated, according to Chairman E. T. Farish. Dinner tables will not be placed on the dance floor. Thus each group will be able to remain at its original tables. Reservations may be made with the Dinner-Dance Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Each table will seat a group of ten persons.

It is expected that the price of the tickets for these two events will be the same as last year, namely, $8 and $11 respectively.

An extensive program for the entertainment of the women attending is being organized under the direction of the Ladies' Entertainment Committee.

HOTEL RESERVATIONS

Members planning to attend the AIEE Winter General Meeting are urged to make hotel reservations now or as early as possible to be sure of accommodations. Blocks of rooms have been set aside at the Hotel Statler (meeting headquarters) and nearby hotels.

Reservations must be made before January 20, 1950, and requests for reservations should be sent directly to the hotel of choice, but only to one hotel. A copy of the request should be sent to C. N. Metcalf, Vice-Chairman—Hotel Reservations, care of the Consolidated Edison Company of New York, Inc., Room 1350-S, 4 Irving Place, New York 3, N. Y., and a second and third choice should be indicated thereon. If accommodations are not available at the hotel of first choice, the Hotel Reservations Committee will arrange for transfer of the request to one of the other meeting hotels. Room rate details will be found on page 1000 of the November issue of *Electrical Engineering*.

Sewaren Generating Station, to be inspected during the Winter General Meeting in New York, N. Y.

Theater Tickets—1950 Winter General Meeting

It is expected that tickets for the following shows will be available to out-of-town AIEE members during the week of the 1950 Winter General Meeting in New York City.

Orchestra Seats: Monday, January 30, through Thursday, February 2, evenings.

Death of a Salesman	$4.80
Kiss Me Kate	6.00
Mr. Roberts	4.80
South Pacific	6.00
(Wednesday matinee, $3.60)	
Where's Charley	6.00

Enclose check in proper amount made payable to "American Institute of Electrical Engineers," with request for reservation and mail to Theater Ticket Committee, care of AIEE, 33 West 39th Street, New York 18, N. Y. Preference will be given to requests for even numbers of tickets. The right is reserved to reduce individual allotments to two seats, if demand exceeds supply for specific shows. In event of sellout, checks will be returned unless second choice of show or date is given.

AIEE/IRE Branch at MIT Reports Year's Activities

With a current membership exceeding 250, the AIEE-Institute of Radio Engineers Student Branch at the Massachusetts Institute of Technology, Cambridge, Mass., reports the end of an extremely active 1948–49 year. The present membership rolls include 103 local members, more than 100 Student members of AIEE, and 50 or more student members of IRE. Jack C. Acton was Chairman for 1948–49.

The group has held a total of 15 meetings the past year, and it has gone out in the field to visit five different plants. These meetings have been varied in nature, as was intended, since the program policy of the organization has been to offer its members and any other interested students and instructors a wide view of the electrical engineering field. Whenever it was practical, a practice of following up a meeting at the school with an appropriate plant trip was used. It was found that this policy of combining a talk and questions at a meeting with further discussion and questions out at a plant offered the interested student a knowledge which might not be usually obtained until he was out of school. The speaker of the evening was requested to bring visual material such as movies or slides; in one or two cases actual demonstrations of

equipment were given. The New England Telephone and Telegraph Company and the General Electric Company offered much valuable help by providing appropriate movies on several occasions.

In the communications field, a meeting was held in which S. V. Stadig, the technical supervisor of nearby *WBZ-TV*, presented the problems of constructing and operating a large television station. This meeting was followed by a plant trip to the station, during which the members were permitted to go through practically every portion of the station. A movie by the Bell Telephone System concerning wartime sonar and radar was followed by a meeting in which Frank D. Lewis of the General Radio Company discussed "Radio Countermeasures in World War II," illustrating his talk with a movie and a demonstration of some of the equipment. The branch then offered its members an insight to the Naval Ordnance Laboratory and the Bureau of Standards in Washington, D. C. The jobs and problems of the government scientist and engineer were thoroughly discussed and were illustrated. Dr. Weller of the Naval Ordnance Laboratory and Mr. Hilsenrath of the Bureau of Standards were the speakers at this meeting.

Shortly before the end of the first semester a special meeting was held at which committees were formed so as to give more of the members an active voice in the programming and policy of the branch. The turnout was good, and the result was that 40 students were formed into groups to plan meetings, trips, publicity, and so forth. As the year progressed new subjects in the electrical engineering field were covered. David Smith, of the Philco Company, came in from Philadelphia to tell the group about the appliance and radio industry, and what the new engineer could do in this field. Later, George Orrok, superintendent of engineering for the Boston Edison Company, gave a talk on the problems of good power plant design, both from the mechanical and electrical standpoints. This meeting was followed by a trip to one of Boston Edison's newest and largest power plants. Next, the branch offered a meeting in which Dr. Kelly of the Bell Telephone Laboratories in New York discussed the problems and relative position of the electrical engineer in research, illustrating his talk with examples of problems from the Bell Laboratories and slides showing the work done there. This meeting was followed by a trip to the Radio Relay Center of the New England Telephone and Telegraph Company. H. H. Scott then talked to the group about his dynamic noise suppressor, which he manufactures, illustrating the discussion with a complete demonstration of the equipment. At the last regular meeting of the year, Dr. Gordon Brown of the MIT Servomechanism Laboratories came to the group to discuss the how and why of servomechanism operation. At an extra meeting, L. S. Cooke, of General Electric, gave a complete talk and demonstration on electric lighting sources.

The branch climaxed the events of the year with a banquet at which Dr. Dana Farnsworth was the principal speaker. A large number of the members were present, and during the evening officers for the next year were installed. Men of industry were invited as guests, and held discussions and answered questions concerning their industries.

New Technical Sessions Featured on Fall General Meeting Program

Presenting a total of 32 technical sessions and conferences, including one general session, the AIEE Fall General Meeting was held in Cincinnati, Ohio, October 17–21, 1949. Headquarters were in the Netherland Plaza Hotel. Several of the meeting's technical sessions marked innovations in the presentation of technical matter before the Institute, such as the sessions on mining and metal industry, aluminum, and cable accessories. Other sessions on rotating machinery, industrial control, and the conferences on machine tools were particularly fitting for presentation in Cincinnati, which is known as the center of the machine-tool industry. Inspection trips to nearby industries, a stag smoker, dinner–dance, and a special program for the ladies completed a profitable and enjoyable week. The total registered attendance of members, guests, and students was 1,045.

GENERAL SESSION

The general session was held on Tuesday morning with a series of three addresses by Dr. Raymond Walters, President, University of Cincinnati; James F. Fairman, President of the AIEE; and Robert S. Peare, Vice-President in Charge of Public Relations of the General Electric Company. Prize-paper awards for District 2 were presented to the winners by Vice-President C. G. Veinott.

ADDRESS OF WELCOME

The general meeting was opened by E. S. Field, General Chairman, who expressed happiness on having the Institute meet in Cincinnati, and told how diligently the local committee had worked on the program arrangement. He introduced President Fairman, who, in turn, introduced Dr. Raymond Walters, President of the University of Cincinnati.

Dr. Walters gave an interesting account of the historical background of the city and the river which was great and colorful 100 years ago. With the passing of the steamboats people bemoaned the fact but the traffic on the river became greater than anyone ever dreamed of. He explained that the lives of the city and the university were entwined, and he referred to the broad diversity of industry found in Cincinnati, ranging from soap and machine tools, to pianos and automobile bodies. Stating that no profession has a higher code than the engineering profession, he pointed out that in 1836 one of the first courses in engineering was established in Cincinnati College and in 1884 a course in civil engineering was begun.

Dr. Walters continued by quoting from an address by Winston Churchill at Boston Garden last Spring during the Mid-Century Convocation at the Massachusetts Institute of Technology, which was considered a great tribute to American education:

> We have suffered in Great Britain by the lack of colleges of university rank in which engineering and the allied subjects are taught. Industrial production depends on technology and it is because the Americans, like the prewar Germans, have realized this and created institutions for the advanced training of large numbers of high-grade engineers to translate the advances of pure science into industrial technique, it is for that reason that their output per head and consequent standard of life are so high.

Dr. Walters said that Mr. Churchill's remarks were based on a parliamentary report in Great Britain and he drew attention to the remarkable group of people England has in pure research, chemistry, and physics; however, he maintained that when it comes to applying that knowledge to manufacturing and mass production, America is far ahead. He attributed our success to the combination of independence and interdependence with, in turn, freedom of thought, and he said that he confidently believes that the technology of this race would win out in the long run.

Dr. Walters paid tribute to Herman Schneider, the founder of co-operative education, and stated that the whole faculty at the university was inspired by him. Pointing out that co-operative education was established at the University of Cincinnati in 1906, he explained that this is no idealistic scheme but that it is a tried and proved method in which industry can co-operate with education. It is a more difficult way, but one way which is exemplified by the 3,000 laboratories and universities which supply the doctors and the reason, or basis, on which we have had the miracle of mass production. In conclusion, Dr. Walters urged that engineers keep in touch with their educational institutions, and in this way

Electrical World photo

At the speakers' table during the general session are shown (left to right): H. H. Henline, AIEE Secretary; Dr. Raymond Walters, President, University of Cincinnati; James F. Fairman, AIEE President; Robert S. Peare, Vice-President of the General Electric Company; C. G. Veinott, AIEE Vice-President

America can fulfill its great destiny. With ample opportunities for leisure and culture, he said that he believes that one of the jobs of the future would be to train for leisure and he appealed for help in the field of education to fulfill the dream of our forefathers and our own high aspirations.

"PROFESSIONAL UNITY AT THE GRASS ROOTS"

In an address, "Professional Unity at the Grass Roots," President James F. Fairman applied the term "grass roots" to the students in the engineering schools who are the future members of the profession. He proposed courses of individual and group action which would benefit the students, the schools, the employers, and the profession. The full text of President Fairman's address appears on pages 1021–3 of this issue.

"THE UNSEEN THINGS IN YOUR PRODUCTS"

An inspiring address, "The Unseen Things in Your Products," was given by R. S. Peare, Vice-President in charge of Public Relations of the General Electric Company. From a long association with engineers, Mr. Peare discussed some of the unseen things in products, such as management, engineering, quality, and ideas of progress. He drew attention to the loss of faith in the idea of progress itself and the sign that we are becoming predominently a society of older people. He attributed to the idea of progress and optimism with respect to the future the fact that we are several steps ahead of the people of any other nation in mass education, production, health, and standards of living. A warning was sounded against this loss of human spirit and optimism for the future which is going on all over the world on a vast scale under centralization and collectivism.

The speaker charged the Institute and engineers with the responsibility of keeping open the roads of progress and productivity. He further cited as a need the responsibility of keeping the public and legislators informed of what makes the systems go and he pointed out as an added responsibility the necessity of helping Americans to really think about and understand business. As a solution to these problems, Mr. Peare cited Russell H. Conwell's "Acres of Diamonds" and he suggested that the place to begin was right in our own backyards, in our homes, our plants, among our associates and employees, and with the teachers in the schools, because it is in the communities where the maximum leverage can be exerted for there personal honesty, open-mindedness, focussed vision, and love of truth have their main chance.

DISTRICT PRIZES FOR PAPERS

Prizes for the District 2 Branch Paper Competition, best paper and initial paper, were presented to the winners by C. G. Veinott, Vice-President of the Middle Eastern District. The awards and the names of the recipients are announced in detail on 1103 of this issue. In making the presentations Mr. Veinott said that in the Institute one has the opportunity to grow and attain recognition which is very well exemplified by the appropriation for technical papers. The advances in the art are all recorded in the AIEE *Transactions* and the Institute has its own 5-foot shelf. The purpose of the prize awards is to simulate interest and individual effort.

INTERSOCIETY RELATIONSHIPS

On Wednesday noon, a trip was taken to the Herman Schneider Memorial Building which serves as a home of the Engineering Society of Cincinnati. This society has 16,000 members affiliated with 22 local sections or chapters of national engineering, scientific, and technical societies, and these sections and chapters, together with the Engineering Society, participate in a program of mutual co-ordination, service, and co-operation through the Technical and Scientific Societies Council of Cincinnati. One of the oldest of engineering societies' councils, the group has long been known for its outstanding work in the community and has served as a model for other groups in various sections of the United States.

Preceding the luncheon, a tour was taken through the Headquarters Building and the Herman Schneider Memorial Library. The building was provided by Cincinnati industry in memory of the late Herman Schneider, Dean of the College of Engineering of the University of Cincinnati, and founder of the co-operative system of engineering education. It is the center for technical society activitie in the community.

During the luncheon, words of welcome were extended and an outline of some of the activities given by E. C. Bolton, President of the Engineering Society of Cincinnati. Officers of the Foundation, the Council, and the Engineering Society were introduced as well as officers of the Institute interested in co-operative activities.

Following the luncheon, a forum was held in the auditorium on Intersociety Relationships in Cincinnati with F. W. Willey, President, The Willey-Wray Electric Company, presiding. The following speakers on the program showed how the Foundation, Engineering Society, and Council complemented and supplemented each other in a comprehensive program of co-operation:

1. "The Headquarters—Herman Schneider Foundation." F. V. Geier, President, The Cincinnati Milling Machine Company, and Foundation President 1944–47.

2. "The Engineering Society of Cincinnati." Hans Ernst, Director of Research, The Cincinnati Milling Machine Company, and Engineering Society President 1948–49.

3. "The Technical and Scientific Societies Council." John Andrews, Assistant Chief Draftsman, The Cincinnati Gas and Electric Company, and Council Chairman 1949–50.

4. "Grass Roots Co-operation in Cincinnati—Fact and Opportunity." A. C. Burroway, Plant Engineer, The Cincinnati and Suburban Bell Telephone Company, and Engineering Society President 1945–46.

Following the presentations, the speakers answered questions that were raised from the floor and a general discussion with respect to integration of the engineering profession took place.

TECHNICAL PROGRAM

The technical program was very broad with a number of sessions in each of the four out of five main groups of Institute activities: communication, industry, science and electronics, and power. Many of the papers in the rotating machinery session, the industrial control session, and in the three conferences on machine tools were of special interest to the machine tool industry and particularly appropriate for presentation in Cincinnati.

Railroad Communication. A conference paper on "Train Communication in Railroad Operations," by F. H. Menagh of the Erie Railroad described about as complete a mobile system as there is in the United States today. Trains cannot get more than 12½ miles from a land station so they are in constant communication with the signal tower or the master dispatcher. In mountainous sections of the railroad, stations are as close together as nine miles so that the trains are never more than four or five miles away. The system is being extended on through to New York and the work will be completed next spring.

Another conference paper entitled "Wire Communication System of the Santa Fe Railroad," by L. R. Thomas of the Atcheson,

Future AIEE Meetings

Winter General Meeting
Hotel Statler, New York, N. Y.
January 30–February 3, 1950
(Final date for submitting papers—closed)

AIEE Conference on Electric Welding
Detroit, Mich.
April 5–7, 1950

AIEE Textile Conference
Georgia Institute of Technology
Atlanta, Ga.
April 13–14, 1950

AIEE Power Conference (Power Generation and Power Supply for Industrial Plants)
Hotel William Penn, Pittsburgh, Pa.
April 19–20, 1950

AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industry
Akron, Ohio
April 1950

North Eastern District Meeting
Sheraton Biltmore Hotel, Providence, R. I.
April 26–28, 1950
(Final date for submitting papers—January 26)

AIEE Conference on Improved Electronic Components and Assemblies
Washington, D. C.
May 8–10, 1950

Great Lakes District Meeting
Hotel Hayes, Jackson, Mich.
May 11–12, 1950
(Final date for submitting papers—February 10)

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(Final date for submitting papers—March 14)

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(Final date for submitting papers—July 5)

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(Final date for submitting papers—July 25)

1951 Winter General Meeting
New York, N. Y.
January 29–February 2, 1951
(Final date for submitting papers—October 31)

Topeka and Santa Fe Railroad treated one of the most extensive private communication networks in the country. The system is comprised of many thousands of miles of carrier telephone and telegraph with communication offices in large centers such as Topeka, Chicago, and Dallas which rival the public communication offices found in many moderate size cities. The Santa Fe also operates automatic reperferator switching techniques such as are used by the large communication companies to eliminate manual retransmission at interconnecting points.

Coaxial Television and Telephone Systems. In a symposium which dealt with the technical design details of this subject, Bell System engineers described the precise techniques required to equalize the delay on coaxial systems to permit handling of television program material. Compensations must be made at the terminals such that the delay in propagation of pulses of a microsecond duration is uniform within a few thousandths of a microsecond. Success in these techniques is evidenced by the excellent quality of television programs now being handled over coaxial cables up to a thousand miles in length.

Radio. In a session on radio, C. J. Hirsch of the Hazeltine Electronics Company told of interesting changes in radio navigation aids which are being made in the networks of airports throughout the country. A distance indicator has been added to the direction-indicating equipment. If the airplane is properly equipped, the pilot can be guided by the airport to any point within 150 miles radius. The pilot pushes a button which asks the question, "How far away am I?" and he gets back an indication in a matter of seconds.

Undervoltage Protection. In a conference on undervoltage protection of motorized drives, five papers were presented which explored present practices in providing instantaneous versus time delay undervoltage protection. A lively discussion ensued which brought out the following points.

Considerable capital has been expended by the power companies to improve the stiffness of the power systems and provide a high degree of continuity of service. Automatic reclosing devices have been installed thereby minimizing the duration and severity of power outages. Hence, the question arises whether it is necessary to shut down motorized drives by instantaneous undervoltage protection in case of voltage loss for a duration of a few seconds. Time delay undervoltage protection would permit motorized drives to restart immediately upon reappearance of voltage provided the disturbances did not last longer than approximately two seconds. The following considerations should govern the choice between instantaneous and time delay undervoltage protection:

1. If loss of voltage should occur, a major portion of the motorized load should be taken off the line immediately to prevent a further system disturbance in case too many motors should attempt to start at the same time.

2. Time delay undervoltage protection should be considered primarily for motors forming part of a continuous process line provided that the loss in motor speed during the power outage causes no damage to the product.

3. Time delay undervoltage protection and consequently automatic restoring of drives should be employed only if the system recovers to substantially full voltage after a disturbance; otherwise, welding of the power contacts might ensue.

Electrical World photo

The winners of the District 2 Prize Paper Contest were (left to right): Richard Sonnenfeldt, Branch Competition Prize; D. S. Stephens, Initial Paper Prize; W. R. Clark and R. E. Tarpley, coauthors with A. J. Williams, Jr. (not shown), winners of the Best Paper Prize

Electrical World photo

Shown at the Fall General Meeting are (left to right): D. T. Michael, Chairman, Registration Committee; J. L. Callahan, Vice-President, AIEE; James F. Fairman, President, AIEE; and E. S. Fields, Chairman of the Fall General Meeting Committee

Mining and Metal Industry. Two sessions in the field of the mining and metal industry culminated the work of a committee started several years ago resulting in a revival of interest in this important subject. In the session on Thursday morning, a conference paper entitled "Analysis of Power Costs of Bituminous Coal Mines" which was presented by H. P. Musser, President of the West Virginia Engineering Company, was of very great interest. Mr. Musser analyzed data over the past 26 years obtained from more than 400 representative mines which quite accurately showed the increase in kilowatt-hours per ton of coal mined, increased mechanization, and a decrease in the cost per kilowatt-hour. The paper indicated definitely an increased use of power in mining coal and an increasing use of electrically controlled and electrically driven mechanized equipment. This will result in a greater demand for trained electrical engineers.

In the afternoon session, an interesting application of telephone carrier to the trolley wires in a mine was presented by W. P. Place of the Farmers Engineering and Manufacturing Company. This constitutes a new and important application of carrier which was reported to have improved the speeding up of operations and in some cases, serious accidents have been averted which would have retarded mining operations.

Rotating Machinery. In a session on rotating machinery held on Monday morning, an important paper entitled "Transient Characteristics of D-C Motors and Generators," by A. T. McClinton, E. L. Brancato, and Robert Panoff of the Naval Research Laboratory was presented. This paper emphasized the importance of the subject to the Navy. Vessels such as large tenders, repair ships, tugs, and submarines have relatively large d-c power plants installed for electric propulsion purposes. Thus the Navy is vitally interested in the question of transient performance of d-c rotating machinery and the effect of the transients on system operation. Of special interest has been that phase of system study work which deals with fault current analysis and the application of protective devices to the power plant. In connection with the design of naval vessels having large d-c propulsion systems, the Navy initiated the development of a completely new design of rotating machinery. It was immediately apparent that if the Navy was to continue using d-c systems, and in some cases this could not be avoided, some means must be established for the accurate calculation of the transient perfomance of d-c machinery from the geometry of the machines concerned. The authors concluded that it is necessary that the theory of transient characteristics of d-c machines be extended to provide the accuracy necessary for attaining the optimum shipboard system design. At the conclusion of this session, the D-C Machinery Subcom-

mittee met and adopted a program for the development of the theory.

In the same session, the AIEE Subcommittee on D-C Machinery presented a second report on its study of temperature rise of d-c machines. It was recommended that Table I of ASA Standard *C50* be superseded by an expanded table to include given values for short time rated machines and for the resistance method for all windings. Following discussion, the subcommittee modified its proposed new table which is to be forwarded to the Standards Committee with the deletion of the values of the resistance method applying to general-purpose motors and generators.

In an afternoon session, a Progress Report on AIEE Test Code for Electric Brushes was presented by a Joint Subcommittee on Electric Brushes. The final stages of completion of this test code are to be done in joint cooperation with the National Electrical Manufacturers Association. In this session, an important paper also was presented on "Motor Tests Evaluate Thermal Endurance of Class-*H* Insulation (Silicone Resin)," by George Grant III, T. A. Kauppi of the Dow Corning Corporation, G. L. Moses, and G. P. Gibson of the Westinghouse Electric Corporation. The paper covered a report on the thermal endurance of insulation with silicone resins. The thermal endurance of this type of insulation was first evaluated by laboratory tests and subsequently by tests on a few isolated machines. It was found that failure of the windings of silicone-insulated motors had been found to occur before the bonding of the resin is seriously weakened and was due to copper conductor failure. The second important conclusion was that class-*H* insulation with silicone resin enjoys a 100 degree centigrade advantage compared with class-*B* insulation. Furthermore, at least seven years of continuous operation at 220 degrees centigrade is required to reach failure of class-*H* insulated equipment. The thermal life of class-*H* silicone-insulated motors was reported to closely follow a 12-degree-centigrade rule.

Among the papers which were presented in the Tuesday afternoon rotating machinery session, "The Torques of the Synchronous Tie—A Steady-State Analysis," by L. A. Finzi and H. M. McConnell of the Carnegie Institute of Technology presented a solution to the very complex problems of this subject which will be exceedingly valuable.

In still another rotating machinery session on Wednesday morning, a valuable paper was presented entitled "Design of Auxiliary Circuits of Single-Phase Induction Motors," by M. S. Thacker and H. V. Gopalakrishna of the Indian Institute of Science. This is one of a series of three papers on the design considerations of single-phase induction motors. When all three papers have been presented and published, the work should constitute a valuable contribution to the literature on single-phase induction motor design. In this session, Professor R. M. Saunders of the University of California presented a very interesting paper in the important field of dynamoelectric amplifiers in which he analyzed the subject from the point of view of steady-state conditions. Most previous work presented has been on the basis of transient conditions.

Rotating Machinery Administrative Subcommittee Meeting. An important meeting of the Administrative Committee of the Rotating Machinery Committee was held Tuesday noon. At this meeting, plans for activities during the coming year were formulated. Major emphasis will be centered on fractional-horsepower machines since during the recent past the principal emphasis has been successively on synchronous machinery, induction machinery, and d-c machinery. The possibility of a technical conference on fractional-horsepower machines and their applications is under consideration.

The "Bibliography of Rotating Machinery," with approximately 1,500 references prepared by Robert Farrell of Fenn College, Cleveland, will be available shortly.

Speed Governing. An interesting session with three valuable papers on the subject of speed governing of large turbine generators was held on Monday afternoon. The Joint AIEE-American Society of Mechanical Engineers Committee on Speed Governing Specifications has virtually finished its assignment. There is urgent need for a test code to test governing systems. Pending the availability of such a test code, operators are studying instrumentation and techniques for determining the characteristics of speed governing systems. The field explored, as described in this session, will be of considerable value in the preparation of a test code.

Cable Accessories. For the first time, a series of papers were presented dealing with the design techniques and manufacture of cable accessories. This innovation will lay the foundation for valuable data in the future. Considerable discussion ensued which centered about the longitudinal stress and creepage in the design of cable joints.

ENTERTAINMENT

Tuesday evening, a stag smoker was held in the Pavilion Caprice which afforded an opportunity for visiting with friends and renewing old friendships. The dinner was followed by a lively series of entertainment of a musical variety, which included also a ventriloquist and an acrobatic act.

On Wednesday evening, the dinner–dance was held, also in the Pavilion Caprice. Between dances, entertainment was provided and appropriate souvenirs were given to the ladies.

The ladies' program, Mrs. Joseph A. Noertker, Chairman, and Mrs. J. P. Quitter, Vice-Chairman, provided an excellent series of events which were thoroughly enjoyed by the ladies. On Tuesday, there was a tour of Procter and Gamble Company, a visit to the Taft Art Museum, followed by a Dutch-treat dinner, with bridge in the evening. On Wednesday, there was a scenic tour, followed by luncheon at the Hyde Park Country Club, and a talk on fashion trends. On return from the country club, there was a stop at the conservatory in Eden Park. The evening was taken up with the dinner–dance. On Thursday, there was a luncheon at the Engineering Society Headquarters. Piano selections were rendered by Mrs. Harry C. King and a book review by Mrs. Walter E. M. Fieldman. A Hostess Parlor was maintained at headquarters under the chairmanship of Mrs. Frank W. Willey and the cochairmanship of Mrs. A. C. Burroway.

INSPECTION TRIPS

During the meeting, an excellent series of inspection trips to nearby industries was arranged. The artistic skill and craftsmanship found on the visit to the Baldwin Company as well as the electronic organ and the acoustic studio and Piano Research Laboratory proved of considerable interest. The Procter and Gamble Company and the Fisher Body Plant of the General Motors Corporation also were visited. In the latter plant, the large presses and stamping machines and the assembly lines were of unusual interest. Other places visited included the Miami Fort Generating Station of the Cincinnati Gas and Electric Company where new construction was seen, the Engineering Society of Cincinnati, the Oakley Colony where milling machines and tools are manufactured, and the Crosley Broadcasting Corporation.

FALL GENERAL MEETING COMMITTEE

The members of the Fall General Meeting Committee which made the arrangements were as follows:

E. S. Fields, *Chairman;* R. J. Rockwell, *Vice-Chairman;* J. P. Quitter, *Secretary;* W. H. McNutt, *Treasurer;* J. C. Strasbourger; E. R. Ramaley; R. E. Stroppel; L. J. Fritz; F. E. Watt; R. D. Spalding

The chairmen of the several working committees were as follows:

Entertainment, S. B. Storer; *Finance,* F. W. Willey; *Hotel and Equipment,* H. E. Barnett; *Inspection Trips,* W. T. Pavely; *Publicity,* R. E. Colado; *Registration,* D. T. Michael; *Transportation,* J. A. Noertker; *Ladies' Program,* Mrs. J. A. Noertker

District 2 Prize Paper Awards Made at Fall Meeting

Award of prizes in the District 2 (Middle Eastern) Prize Paper Competition, covering the period from January 1, 1948, through July 31, 1949, was made at the Fall General Meeting in Cincinnati, Ohio, on October 18, 1949. Of the 41 papers submitted by the Sections, the following papers were selected for honors:

Best Paper Prize: "D-C Amplifiers Stabilised for Zero and Gain," A. J. Williams, Jr., R. E. Tarpley, W. R. Clark (Philadelphia Section)

Best Initial Paper Prize: "Lightweight Aircraft Transformers," Donald S. Stephens (Sharon Section)

Presentation of the certificates and the $25 prizes was made by C. G. Veinott, Vice-President of District 2, and a similar award was made at the same time to Richard W. Sonnenfeldt of Johns Hopkins University, the winner of the District Branch Prize Paper Competition for 1949 held at the Carnegie Institute of Technology on April 29 and 30. Mr. Veinott traced the opportunity for recognition and reward which the Institute offers to all members, from the student just beginning his career, through the young engineer becoming established, to the mature engineer pushing the frontier of electrical engineering ever further into the unknown.

The District Prize Paper Competition included all papers presented within or under the auspices of District 2 provided the author or at least one of the coauthors was a member of the Institute located within District 2. The judges who undertook the task of considering the papers and choosing the final winners were

R. C. McMaster (*Chairman*), Columbus Section; A. J. B. Fairburn, Cleveland Section; J. B. Hodum, Pitts-

burgh Section; H. J. Talley, Philadelphia Section; R. C. Wey, Canton Section

It is of interest to note that the $25 cash awards for Best Initial Paper and Best Paper were made possible by contributions from all Sections and District officers. These contributions were solicited when the District 2 Executive Committee, at a meeting in Washington on October 4, 1948, observed that the Institute had made no money available for Section prizes and, realizing that competition would be spurred on by cash awards, it was decided to invite contributions from the Sections toward a prize fund.

Executive Committee Meets for AIEE Southern District

With an attendance of 21 members, as well as several visitors, the Executive Committee of the AIEE Southern District (4) met in the Electric Power Board Building in Chattanooga, Tenn., on Friday, October 7, 1949.

The meeting began with an abstract of the previous meeting in November 1948, followed by a report by J. D. Harper, Vice-Chairman of the Membership Committee. He emphasized the need for activity in the individual Sections, activity which should stress the importance of securing applications from Student members whose terms are about to expire, as well as obtaining new members from the profession who have the necessary qualifications. Also, the use of the Membership Booklet was stressed. The possibility of using badges at the meetings, showing the member's name and affiliation, was discussed, and the formation of a Transfer Committee in each Section was advised in order to raise the membership grades to as high a level as possible.

Professor Pumphrey, the Sections Committee Representative, reported on the activity of the Sections Committee. General discussion of his remarks included the idea of local members, and the change in the ruling for paper prizes. Discussion also included the support of Student Branch meetings financially.

The Chairman of the Committee on Student Branches, Professor H. B. Duling, discussed the need for incentive in obtaining student papers. It was suggested that the competition in the Student Branches be held in the month of January with the winning papers for the final competition to be filed in March.

In the matter of a member for the Nominating Committee, J. E. Housley, Past President of the Institute, was elected to serve on the committee for the Southern District.

After luncheon, Vice-Chairman Seeley discussed the reaction to the type of organization that the AIEE should be as it was voiced at the Summer General Meeting at Swampscott. Considerable discussion was evoked from the members and it appears that more comment on this highly controversial subject from the Sections will be forthcoming.

Attending the AIEE Southern District Executive Committee Meeting in Chattanooga October 7, 1949, are, reading from left to right, bottom row: Ira H. McMann, Chairman Western Virginia Section; E. S. Lammers, Jr., Chairman, Georgia Section; P. R. Spracher, Secretary, Virginia Section; C. H. Summers, Chairman, Miami Section; Professor Walter J. Seeley, Vice-President, Southern District; T. H. Mawson, Secretary, Southern District; T. DeWitt Talmage, Host and Chairman, East Tennessee Section; J. D. Harper, District 4 Vice-Chairman, Membership Committee; R. D. Spalding, Chairman, Louisville Section; L. Saunders, Chairman, Virginia Section. Top row: John D. Sharp, Jr., Host and Secretary, East Tennessee Section; H. E. Pritchard, Jr., Secretary, New Orleans Section; H. T. Smith, Secretary, Louisville Section; E. P. Miller, Chairman, South Carolina Section; W. M. Stanley, Host and Chairman of Meetings and Papers Committee, East Tennessee Section; H. P. Peters, Secretary, Georgia Section; C. M. L. Pons, Secretary, Shreveport Section; W. T. Edwards, Jr., Chairman, Miami Section; R. M. Alspaugh, Host and Vice-Chairman, East Tennessee Section; Professor H. B. Duling, Chairman, District 4 Committee on Student Activities; G. G. Mattison, Chairman, North Carolina Section; R. A. Merrill, Host and Associate Professor of Engineering, University of Chattanooga, East Tennessee Section; B. V. Martin, Secretary, North Carolina Section; E. I. Blanchard, Chairman, New Orleans Section; and F. H. Pumphrey, Sections Committee

Wichita Section Chairman

Above is Robert F. Dice, Chairman of the AIEE Wichita Section for 1949–50. Mr. Dice's photograph arrived too late for inclusion in the picture display feature, "Introducing AIEE Section Chairmen for 1949–50" which appeared in the November issue (EE, Nov '49, pp 1002–50)

Portland Section Sponsors Power System Relaying Course

A course in Modern Power System Relaying, given by the Portland Extension Center of the Oregon State System of Higher Education and sponsored by the AIEE Portland Section, has met with such enthusiastic response that classes are being held in the auditorium of a local high school. Present enrollment is 108 and includes engineers from public and private utilities, Bonneville Power Administration, and the United States Engineers.

The class is under the supervision of Professor E. C. Starr, Department of Electrical Engineering at Oregon State College, with instruction by Myron A. Bostwick, Relay Engineer, Portland General Electric Company, and Clifford Diemond, Relay Engineer for Bonneville Power Administration. Classes are conducted as lectures with emphasis being placed on practical application rather than pure theory.

Michigan Section Holds Silver Anniversary Meeting

On October 18, 1949, more than 200 members and guests attended the AIEE Michigan Section's Silver Anniversary Meeting in the Ballroom of the Hotel Hayes in Jackson, Mich. This meeting marked the 25th anniversary of a series of meetings which have been held annually in Jackson, without interruption, since 1924, and a special program was arranged to honor the occasion.

The meeting was opened by E. F. Dismeyer, Chairman of the Michigan Section, who introduced the Honorary Chairman for the evening, J. C. Langdell (A '07, F '47) of Commonwealth Services, Inc. Nine of the 11 charter members were present and sat at the speakers' table. They were: Frank G. Boyce (A '12, F '45) Consumers Power Company; James H. Foote (A '18, F '32) Commonwealth Services, Inc.; John G. Hemstreet (A '21) Consumers Power Company; Earl E. Norman (A '20) Light and

Seated at the speakers' table during the AIEE Michigan Section's Silver Anniversary Meeting in Jackson are shown, left to right: Joseph C. Langdell, Frank G. Boyce, John Hemstreet, and Harold Plumb. Standing, left to right, are: E. F. Dissmeyer, Chairman of the Michigan Section; Melvin J. Evans, principal speaker of the evening; Roy L. Rinker, E. V. Sayles, John R. North, and James H. Foote

Water Utilities, Kalamazoo, Mich.; John R. North (A '21, F '41), Commonwealth Services, Inc.; Harold J. Plumb (A 23, M '34) Consumers Power Company; Roy L. Rinker (A '19) Consumers Power Company; Edgar V. Sayles (A '23, F '38) Consumers Power Company; and Mr. Langdell. Those unable to attend were: William M. Gokay (A '15), A. E. Kriegsmann (A '14, M '26), both with Consumers Power Company. Also, D. R. Stratton (A '20, M '42) Commonwealth Services, Inc., who should have been included but was not invited to sit at the speakers' table because the AIEE Year Book did not show the date that he joined the Institute. Other members for more than 25 years were introduced from the floor.

Following the introductions, a welcoming address was given by F. G. Boyce. J. H. Foote then introduced the principal speaker of the evening, Melvin J. Evans of the Melvin J. Evans Company of Chicago, who spoke on "Human Engineering Makes Better Jobs."

The AIEE Michigan Section had its beginning as the "The Detroit–Ann Arbor Section" when authorized on January 13, 1911. That name was changed to "The Michigan Section" on June 23, 1938. The city of Jackson, site of the Silver Anniversary Meeting, has consistently been noted for the highest total AIEE membership per unit of population in Michigan.

Milwaukee Section Holds Successful Opening Meeting

The AIEE Milwaukee Section's program for 1949–50 got off to an auspicious start on October 5, 1949, with an unprecedented Ladies Night opening meeting at the Allen-Bradley Company.

After a smorgasbord dinner, the 700 members and guests of the Milwaukee Section who attended gathered in Lynde Hall where F. Van Zeeland, Chairman of the Section, gave the opening welcoming address. He then turned the meeting over to E. A. Dickinson, Program Chairman, who acted as Master of Ceremonies for the evening. The main entertainment was provided by the Milwaukee Norman Players, an amateur theatrical group which presented a play entitled, "Moon Over Mulberry Street," and the evening closed with refreshments and a social get-together.

Art Graettinger, AIEE Program Committee member from the Allen-Bradley Company, was in charge of arrangements for the meeting. Photographs were taken by J. M. Hopwood, Publicity Committee, and an Allen-Bradley photographer.

Through co-ordinated action on the part of the Program, Membership, and Publicity Committees, an unusually successful season is anticipated. The men heading these committees are

Publicity Committee: L. V. Saari, *Chairman;* C. C. Corey, *Vice-Chairman*

Membership Committee: R. C. Ball, *Chairman:* V. H. Simon, *Vice-Chairman*

Program Committee: E. A. Dickinson, *Chairman;* B. G. Wheeler, *Vice-Chairman*

Members and guests of the AIEE Milwaukee Section enjoying a smorgasbord dinner at the Section's opening meeting of the 1949–50 season on October 5

COMMITTEE NOTES •

Editor's Note: This department has been created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Power Conference Scheduled for Pittsburgh, April 1950

A Special Technical Conference, which is being sponsored by the AIEE Committees on Power Generation, System Engineering, and Industrial Power Systems, and is to be devoted to power generation and industrial power systems, will be held at the William Penn Hotel, Pittsburgh, Pa., April 19 and 20, 1950. A very diversified program is being planned to attract as large an attendance as possible and ensure active discussion.

The Committee on Power Generation will contribute the program for the first day, April 19, which will include a morning and afternoon session. The morning session will cover the planning problem, including such subjects as: "Elements of System-Capacity Determination"; "Economic Evaluation of Steam Station Prime-Mover Arrangement"; "Elimination of Distribution Galleries in Metropolitan Generating Stations"; and "Designing Fire Fighting Layouts." The afternoon session will deal with the operating problem and will cover: "Maintenance and Overhaul Scheduling"; "Steam Station Efficiency Control"; "Efficient Use of Operating Personnel"; and "Improved Storing, Accounting, and Stocking of Spare Parts."

This will be the first Special Technical Conference to be sponsored by committees within the Power Group. The complete program, including the industrial power systems and system engineering part of the conference on April 20, will appear in a later issue of *Electrical Engineering*.

Communication Group

Committee on Communication Switching Systems. (*R. C. Davis, Chairman; J. Meszar, Vice-Chairman; A. E. Frost, Secretary.*) The first meeting of this recently formed committee was held on September 15, 1949, in the business office of the chairman, at Bell Laboratories. Six of the 12 members attended. It was an informal session devoted to getting acquainted, and to starting the preparation of plans for the Winter,

Summer, and Fall General Meetings of next year.

The committee decided to sponsor three interesting technical papers for the Winter General Meeting. These are

1. "The Number 5 Crossbar Dial Switching System," by F. A. Korn and J. G. Ferguson of Bell Laboratories.

2. "The Automatic Telephone Message Accounting System," by J. Meszar of Bell Laboratories.

3. "Basic Theory Underlying Bell System Facilities Capacity Tables," by A. L. Gracey of the American Telephone and Telegraph Company.

There was also a discussion of tentative papers to be sponsored by the committee for the Summer General Meeting in Pasadena. When the subjects of these papers crystallize, they will be announced in a subsequent issue of *Electrical Engineering*.

General Applications Group

Aircraft Electric Systems Subcommittee of Committee on Air Transportation. (*G. A. Phillips, Chairman.*) During the past year, under the chairmanship of W. F. Moore, various sections of the Aircraft Systems Guide were assigned to members of this subcommittee and work is under way on the following sections: Appendix 1, entitled "Methods of Evaluating Electric Loads"; Appendix 2, covering "Methods of Computing Momentary Voltage Dips and Overvoltages" (this is a very controversial section of the guide and testing will be accomplished by the Naval Research Laboratory on the theoretical analysis—the Research Laboratory has secured special oscillographic instrumentation, which will be suitable for measuring the phenomenal without undue distortion); Appendix 3, "Methods of Computing Short-Circuit Currents"; sections covering lighting, electronic equipment, heaters, and actuators; and "Control." Discussion took place with the Aircraft Electrical Control Protective Devices Subcommittee in connection with installation procedures (such as installation of cabling, terminals, standardization of wiring diagrams, cooling, bonding) being expanded beyond that of existing specifications. Such information may be incorporated in the Systems Guide or issued as a separate report on installations. A group of Sections on Protective Principles and General Systems Design needed assistance and volunteers for editing and collecting information were solicited.

Committee on Domestic and Commercial Applications. (*Carl F. Scott, Chairman; O. K. Coleman, Vice-Chairman; V. G. Vaughan, Sr., Secretary.*) The subject of electric heating of homes, including heat pumps, continues to attract wide-spread interest. Manufacturers, architects, contractors, home owners, and public utilities are giving the subject a good deal of study. Already in the Tennessee Valley more than 18,000 homes have been heated electrically. Following the conference on this subject at the August 23 meeting in San Francisco, it is planned to have a session in the East in January.

The committee plans to appoint two subcommittees on this one phase of its activities, one for the Pacific Coast and one for the East. It also plans a subcommittee on domestic appliances.

Science and Electronics Group

Magnetics Subcommittee of Committee on Basic Sciences. (*T. D. Yensen, Chairman; H. G. Zambell, Secretary.*) This subcommittee has been actively engaged in planning the programs for the coming year. It has succeeded in lining up a most interesting symposium for the coming Winter General Meeting. This symposium will be divided into four sections: "Magnetostriction," which will include its measurement, single crystals of iron-silicon, and permanent magnets and other materials; "Commercial Magnetic Materials," including recent developments in commercially available magnetic materials, and the properties of electrical sheets for rotating machinery; "Magnetic Anisotropy," including growing oriented crystals and their magnetic properties, materials for magnetic amplifiers, and magnetic anisotropy in single crystals of Fe-Co alloys; and "Miscellaneous," covering the recording fluxmeter, and magnetic powders.

Electronic Converter Application Subcommittee of Committee on Electronic Power Converters. (*W. N. Farquhar, Chairman; J. B. Donnelly, Secretary.*) The 1948–49 Application Subcommittee prepared a questionnaire which was sent to all mercury-arc rectifier users in America. The questionnaires covered pertinent data regarding the rectifier installations. The present subcommittee is now in the process of tabulating the information received in the returned questionnaires. A preliminary report on the survey was presented at the Fall General Meeting at Cincinnati, Ohio, in October. A complete report will be prepared for presentation at a future meeting during 1950.

Subcommittee on Electronic Power Converter Circuits. (*I. K. Dortort, Chairman.*) A report on Protection of Electronic Power Converters in two parts has been published in advance-copy form. Part I was presented at the Winter General Meeting in New York, and Part II was presented at the Fall General Meeting in Cincinnati, October 21.

Parts I and II are now being integrated for publication in the *Transactions*. It is hoped this work can be accomplished in time to present the completed report, by title, at the coming AIEE Winter General Meeting.

The subcommittee will sponsor papers and may prepare reports on the problem of voltage surges, equivalent machine constants, a survey of industry's experience with and handling of fault currents. Other projects under consideration include dynamic and regenerative braking of loads supplied by rectifiers, balancer sets, power-factor correction and metering, and terminology for electronic motor drives (in conjunction with other committees).

Industry Group

Committee on Chemical, Electrochemical, and Electrothermal Applications. (*F. R. Benedict, Chairman; LeRoy W. Roush, Vice-Chairman.*) This technical committee is planning expanded activities in 1950. All of the subcommittees are actively engaged in important engineering work in their respective fields.

The problem of charging and maintenance of storage batteries is gaining in importance and the Storage Battery Subcommittee, with H. C. Riggs, Chairman, is comprehensively studying this problem to eliminate inconsistencies in storage battery practices. The committee is formulating a report on Recommended Practices, which should be available in 1950.

Applications of equipment in the chemical industries present many specialized problems, which are being actively studied by L. W. Roush's Chemical Industries Subcommittee. Switchgear, control devices, and power cables and wiring are of particular importance and recommended practices are being formulated. The subcommittee is planning two sessions on "Power Cables for Chemical Applications" for the Winter General Meeting in 1950. One session will relate to cable manufacture and the other to cable operation.

The Subcommittee on Electrolytic Processes, with W. E. Gutzwiller, Chairman, is continuing its work on matters relative to theory, technique, plant efficiency, application of power conversion equipment, and operating hazards. The subcommittee is now engaged in preparation of a report on the influence of electrolytic cell line characteristics on the selection of power and conversion equipment.

AIEE PERSONALITIES.....

F. B. Jewett (A '03, F '12, HM '45, Member for Life), former President of the National Academy of Sciences and a Past-President of AIEE, has been awarded the Hoover Medal for 1949, one of the highest awards in the engineering profession. (Dr. Jewett was Vice-President in Charge of Development and Research at the American Telephone and Telegraph Company for nearly 20 years (1925–44), and President of the Bell Telephone Laboratories, New York, N. Y., from 1925 to 1940.) The medal is awarded by the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, and the AIEE, and will be presented to Dr. Jewett at the Winter General Meeting of the last-named society, January 30–February 3, 1950, in New York, N. Y. First awarded to Herbert Hoover in 1930 and named for the former President, the medal is given "by engineers to a fellow engineer for distinguished public service." In addition to receiving the Hoover Award, Dr. Jewett recently was named winner of the 1950 Medal of the Industrial Research Institute, Inc., "for outstanding accomplishments in leadership in management and industrial research which contributes broadly to the development of industry or the public service." A native of Pasadena, Calif., born September 5, 1879, Dr. Jewett was graduated

F. B. Jewett

from Throop Polytechnical Institute, now the California Institute of Technology, in 1898. He did advance study in electrical engineering under A. A. Michelson at the University of Chicago and then taught electrical engineering and physics at the Massachusetts Institute of Technology, Cambridge. He joined the American Telephone and Telegraph Company in 1904 and in 1912 was named Assistant Chief Engineer in the Western Electric Company. Four years later, he was named Chief Engineer. In 1925, he was elected a Vice-President of the American Telephone and Telegraph company, a member of the Board of Directors of the Long Lines Department of that company, and President of the Bell Laboratories. Dr. Jewett has received a large number of honorary degrees and awards. Some of the latter include the Edison Medal (1928), the Faraday Medal (1935), the Washington Award (1938), and the Medal for Merit (1946). He holds membership in the American Association for the Advancement of Science, the Institute of Radio Engineers, the American Physical Society, the Society for the Promotion of Engineering Education, and the Institution of Electrical Engineers (British). Some of the AIEE committees on which he has served are: Edison Medal; Executive Medal; Protective Devices; Research; Standards; Engineering Foundation Board; Education; Hoover Medal Board of Award; Lamme Medal; and Co-operation With War Agencies.

C. M. Slack (M '43) has been named Technical Director of the Westinghouse Electric Corporation's Atomic Power Division in Pittsburgh, Pa. He will have responsibility for the general direction and co-ordination of all research and engineering work of the division. The first major project of the division is the building of an atomic power plant for Naval ship propulsion in co-operation with the Argonne National Laboratory of Chicago under contract awarded by the Atomic Energy Commission. Born in Marietta, Ohio, December 4, 1901, Dr. Slack was graduated from the University of Georgia in 1922 with a bachelor of science degree. He received his master of arts degree from Columbia University in 1923 and his doctor of philosophy from Columbia in 1926. He spent the next year, until accepting a Westinghouse position, as a physics instructor at Columbia University, New York, N. Y. Dr. Slack's entire career with Westinghouse has been in the Lamp Division Laboratory at Bloomfield, N. J. He joined Westinghouse as a physicist in 1927, became Assistant Director of Research for the division in 1943, and was named Research Director in 1946. In 1945, Dr. Slack was awarded the Westinghouse Order of Merit, highest company honor, for his work in developing high-speed X-ray and other electronic tubes and apparatus. During the war, his millionth-of-a-second X-ray tube proved valuable to government arsenals and proving grounds where scientific ballistic studies were underway. Dr. Slack is a member of the American Association for the Advancement of Science and the American Physical Society. At present, he is serving on the Therapeutics Committee.

H. A. Frederick (A '12, F '28, Member for Life), Director of Switching Apparatus Development, Bell Telephone Laboratories, New York, N. Y., has retired. Replacing Mr. Frederick is **A. C. Keller** (A '47), who was Switching Apparatus Engineer on the former's staff. The retiring engineer joined the Laboratories in 1912, after receiving his electrical engineering degree from Princeton University. His first job was in the Research Department. He was transferred to Transmission Development Department in 1914, where he designed one of the earliest of operator receivers using silicon-steel pole pieces. Six years later, he became head of the telephone instruments development group in the Research Department. In 1935, Mr. Frederick was designated Director of Electromechanical Apparatus Development. Since the war, as Director of Apparatus Development, he has been responsible for designs of new types of relays, the trouble recorder for crossbar offices, card translator for the nation-wide dialing program, apparatus for automatic message accounting, and cost reduction studies. Mr. Frederick is a member of the Acoustical Society, the American Physical Society, and the American Association for the Advancement of Science. Mr. Keller, who succeeds Mr. Frederick, joined the Laboratories in 1917. Possessor of degrees from Cooper Union and Yale, he took an active part, in World War II, in the development of submarine detection and signaling devices. Mr. Keller is a member of the Acoustical Society, the Institute of Radio Engineers, the Society of Motion Picture Engineers, and the Physical Society.

Harvey Fletcher (M '23, F '30), who retired in October as Director of Physical Research at the Bell Telephone Laboratories, New York, N. Y., was awarded the 1949 Progress Medal of the Society of Motion Picture Engineers at the Society's 66th semi-annual banquet. In the presentation of the medal, Dr. Fletcher was cited for his outstanding achievements in motion picture technology leading to the advance of the motion picture art and industry. Also, in the citation, his research was credited with having led to the development of sound motion pictures. In 30 years of teaching, research, and development work, Dr. Fletcher has contributed toward an understanding of the fundamental nature of speech and hearing. The results of his research have been applied to telephone devices, electric recording, high-fidelity loud-speakers, as well as to sound motion pictures. Dr. Fletcher was born in 1884 in Provo, Utah. He received a bachelor of science degree from the Brigham Young University in 1907 and a doctor of philosophy degree from the University of Chicago in 1911. He returned to the Brigham Young University as professor of physics in 1911, leaving it in 1916 to join the Research Department of the Bell Telephone Laboratories. He was appointed Director of Physical Research in 1933.

R. H. Earle (A '27, M '29) has been promoted to Chief Engineer for Product Engineering at the South Milwaukee (Wis.) branch of the Line Material Company. In other company changes, **Anthony Van Ryan** (A '44) has been named to head New Product Development; formerly he was with the Kyle Corporation in South Milwaukee. **M. F. Beisber** (A '37, M '45), previously Manager of Line Material's Transformer Sales Department at Zanesville, Ohio, has been designated Manager of Marketing. **E. W. Williams** (A '45), formerly with the Kyle Corporation, directs the company's new Sales Promotion Department. Named to fill Mr. Beisber's former position is **A. B. Coyle** (A '46), who, in the past, was Wired Radio Sales Manager at Line Material's East Stroudsburg (Pa.) office.

F. J. Meyer (A '13, F '36), Vice-President in Charge of Operations, the Oklahoma Gas and Electric Company, Oklahoma City, has retired after 47 years of service. Starting as a lineman's helper, Mr. Meyer served as Chief Electrician, Superintendent of the Gas Department, Electrical Engineer, General Superintendent, and Assistant General Manager, and in 1931 was elected to the position he held at the time of his retirement. Mr. Meyer was Vice-President of the Institute, 1934–36, and a Director from 1939 to 1943. He has been active in the affairs of the Oklahoma Utilities Association for a number of years.

L. A. Doggett (A '13, F '36), who retired as Emeritus Professor of electrical engineering at the Pennsylvania State College on January 1, 1949, served as interim Professor of Electrical Engineering at the University of Florida, Gainsville, from February to June of this year. He is now serving as visiting Professor of Electrical Engineering at Bucknell University, Lewisburg, Pa. Mr. Doggett is a Member for Life.

F. L. Snyder (M '46) has been named Manager of the Transformer Division, Westinghouse Electric Corporation, Sharon, Pa. Succeeding Mr. Snyder as Transformer Division Engineering Manager is **J. H. Chiles, Jr.**, (A '26, F '48); **R. L. Brown** (M '42) fills Mr. Chiles' former post of Division Engineer. All three men have been associated with Westinghouse for their entire business careers, Mr. Snyder and Mr. Chiles since 1925 and Mr. Brown since 1922.

Charles Ganther (A '39, M '48) has been appointed Superintendent of the Electrical Department of the Cleveland (Ohio) Electric Illuminating Company, succeeding **A. H. Nicholson** (A '25), retired. Associated with the firm since 1928, Mr. Ganther's former designation was Assistant Superintendent of the Electrical Department. Mr. Nicholson had been with the company since 1905.

OBITUARY ....

Henry Morton Brinckerhoff (A '96, M '96, Member for Life), inventor of the third rail used for electric railways and a partner in the consulting engineering firm of Parsons, Klapp, Brinckerhoff, and Douglas, New York, N. Y., died October 12, 1949, at his home in Englewood, N. J. Five years ago, Mr. Brinckerhoff was appointed one of three engineering consultants by Governor Dewey of New York to plan for the Thruway from Buffalo, N. Y., to New York City, this parkway being Mr. Brinckerhoff's final engineering undertaking. He had a part in equipping the New York Interboro Company's subway system, the Queensboro Tube, The Detroit–Windsor, Ontario, Canada, tunnel, and the elevated railway system of Chicago. He also served as consultant for the city of Chicago in planning its new subway, and was consultant for construction of the New York World's Fair. Mr. Brinckerhoff served as General Manager of the Metropolitan Elevated Railway Corporation, Chicago, Ill., and as President of the Mohawk Hydroelectric Company and the Fulton Company of New York. The engineer was the first chairman of Englewood's City-Planning Board, established to meet problems caused by the construction of the George Washington Bridge. Born April 20, 1868, in Beacon, N. Y., Mr. Brinckerhoff was graduated from the Stevens Institute of Technology in 1890 with a degree in mechanical engineering. He held memberships in the American Society of Civil Engineers, the Western Society of Engineers, and the Engineers' Club of New York. He belonged to the old Traction and Transportation Committee, 1914–16 and 1921–22, serving as its Chairman during the latter interval, and was a member of the former Meetings and Papers Committee, 1921–22.

John Murphy (A '00, M '01, F '13, Member for Life), Senior Electrical Engineer with the Canadian Government's Department of Transport, Ottawa, Ontario, Canada, on his retirement in 1938, died September 23, 1949. In addition to holding the aforementioned post, Mr. Murphy was Acting Superintendent of the Rideau Canal during his last four years with the government. A native of Ottawa, born December 17, 1868, Mr. Murphy joined the Chaudiere Electric Light and Power Company in 1887. Four years later, he was placed in charge of the power plants of both the newly formed Ottawa Electric Railway Company and the Chaudiere firm. He continued as an employee of these two utilities for the next 20 years, at the same time engaging in a consulting engineering practice. In 1906, Mr. Murphy began his 32-year association with the Canadian Government, starting as an electrical engineer with the Department of Transport (then called the Department of Railways and Canals). Subsequently, he became a member of the Board of Railway Commissioners. Active in technical organizations, Mr. Murphy was Past-Chairman of the Ottawa branch of the Engineering Institute of Canada, served as President of the Canadian National Committee, International Electrotechnical Commission from 1927 to 1937, and as official delegate to the World Power Conference in 1924 and in 1930. He also worked with the Canadian Engineering Standards Association and held membership in the Canadian Electrical Association. Mr. Murphy served on the old Traction and Transportation Committee, 1916–22, and the Transportation Committee, 1925–38.

Robert B. Ely (A '41), Chief Airport Lighting Engineer, Civil Aeronautics Administration, Chicago, Ill., died July 6, 1949. Noted as a lighting expert, Mr. Ely began his industrial career with the Philadelphia (Pa.) Electric Company in 1901. During the next 16 years, he worked in most of the utility's departments, and also inaugurated the lighting service department. In 1917, Mr. Ely joined the Westinghouse Electric Corporation. There, he was in charge of educational courses for salesmen and designed many street and airport lighting installations. The lighting of the Cape Cod Canal was one of his projects. Mr. Ely became associated with the Daunt Corporation, Long Island City, N. Y., in 1940, where he was in charge of engineering and sales. In the following year, he left to supervise electrical installations for military airports and fortifications for the United States Engineer Office at Charleston, S. C. In 1944, he went to Chicago, Ill., to join the Civil Aeronautics Administration. Mr. Ely was an active member of the Illuminating Engineering Society, having contributed several articles to their early *Transactions*, and having served as Director of the society from 1921 to 1924 and Chairman of their New England Section. A native of Philadelphia, Pa., he was born October 10, 1884, and was educated at Johns Hopkins University.

David Fowler Atkins (A '07, M '16, Member for Life), a consulting engineer, Flushing, N. Y., died January 8, 1949, according to a notice received recently by the Institute. Born in Westfield, Mass., December 16, 1869, Mr. Atkins was graduated from Worcester Polytechnic Institute in 1891 with a bachelor of science degree in mechanical engineering. In the latter year, he became Chief Draftsman at the Foundry and Machine Works, Harrisburg, Pa. After holding that position for five years, he went to Rio de Janeiro, Brazil, where he was engineer in charge of the operation of two electric railways and one small lighting plant. In 1898, he joined the Armington Sims Engine Company, Providence, R. I., as a designer, and the following year he accepted a similar post with McIntosh, Seymour, and Company, Auburn, N. Y. Mr. Atkins was designated Engineering Inspector, Architect's Office, United States Treasury Department, Washington, D. C., in 1901, holding that position until 1914. Next, he became Chief Engineer of Light and Power, Bureau of Gas and Electricity in New York City's Department of Water Supply, Gas, and Electricity. Appointed Mechanical Engineer for the Lord Electric Company, New York, N. Y., in 1919, he joined the Chicago Pump Company, New York, N. Y., four years later. In 1925, he became a consulting engineer, and he worked in that capacity for the remainder of his business career.

Joseph Elbert Woods (M '48), Senior Distribution Engineer, Central Power and Light Company, Corpus Christi, Tex., died September 18, 1949. A native of Corsicana, Tex., he was born September 22 1899. After being graduated from the Agricultural and Mechanical College of Texas in 1921, with a bachelor of science degree in electrical engineering, he joined the Texas Power and Light Company, Dallas, Tex., as a rate clerk. Later, he worked on a substation maintenance crew and in merchandise sales, being promoted to Transmission Engineer in 1924. In 1927, he became Transmission Engineer and Assistant to the Chief Engineer for the Central Power and Light Company, San Antonio, Tex. Five years later, the company designated him District Engineer and Assistant District Manager of the Guadalupe District. Appointed District Engineer in Corpus Christi in 1939, Mr. Woods advanced to Senior Distribution Engineer in 1945. He was a member of the Texas Society of Professional Engineers and the South Texas Engineers' Club, and served as Chairman of the San Antonio Section during 1930–32.

Edmund Oscar Schweitzer (A '99, F '20, Member for Life), Chief Testing Engineer for the Commonwealth Edison Company, Chicago, Ill., on his retirement in 1936, died September 22, 1949. A native of Chicago, born October 10, 1875, he received a bachelor of science degree in electrical engineering from Purdue University in 1898. Following his graduation, he began a 38-year association with the Commonwealth Edison Company, starting as an electrical inspector. He was appointed Testing Engineer in 1902 and Chief Testing Engineer in 1909, holding the latter post until he retired. For 19 years, he was President of the S and C Electric Company and was the joint inventor of the Schweitzer and Conrad extra-high-potential fuse and Schweitzer and Conrad lightning arresters. In addition, he invented the automatic instantaneous regulator and the recording synchroscope. The author of numerous papers on cable problems, he was a member of the Illuminating Engineering Society, the American Mathematics Society, and the Western Society of Engineers, and a past member of the National Research Council.

Frank Rogers Bacon (A '10, M '20, Member-for-Life), one of the organizers of the Cutler-Hammer, Inc., Milwaukee, Wis., died October 6, 1949. A native of Milwaukee, he was born September 28, 1872. After attending Princeton University for one year, he left school to enter his father's grain business, but soon became interested in the electrical industry. In 1896, he formed the American Rheostat Company, a Wisconsin corporation, becoming its president. Three years later, he organized the Cutler-Hammer company as a Wisconsin corporation, merging the American Rheostat Company and the Cutler-Hammer Manufacturing Company of Illinois. Mr. Bacon was President of the consolidated company until 1924, Board Chairman from 1924 to 1931, and both President and Board Chairman from 1931 to 1945. During his life, he had numerous other business connections. He assisted in organizing the Lackawanna

Bridge Company, Buffalo, N. Y., in 1909 and was Vice-President until his resignation in 1922. He was Vice-President of the Niagara Smelting Corporation and President of the S and C Electric Company, Chicago, Ill. His professional affiliations included membership in the Engineering Society of Milwaukee, the New York Engineers' Club, and the Electrical Manufacturers Club.

Martin Berthold (A '08, M '14, Member for Life), President, Berthold Electric and Engineering Company, Akron, Ohio, died October 16, 1949. Identified with the aforementioned company since 1923, Mr. Berthold was born in Oberholz, Saxony, Germany, on September 6, 1877. He was educated in his native country, and started his business career there with Dr. G. Langbein and Company in Leipzig, working on motor and generator design. In 1902, he came to the United States, and joined the Western Electric Company, Chicago, Ill., as a technical clerk in the dynamo-testing department. Three years later, he was employed as an assistant electrical engineer with the Commercial Electric Company (predecessor to the Fairbanks Morse Electrical and Manufacturing Company), Indianapolis, Ind. Designated Chief Engineer for the Ideal Electric and Manufacturing Company, Mansfield, Ohio, in 1909, Mr. Berthold accepted a similar post with the Imperial Electric Company, Akron, three years later and remained there until 1923.

Ivan S. Rice (A '27, M '44), Assistant Superintendent of Substations, Commonwealth Edison Company, Chicago, Ill., died August 11, 1949. Born August 24, 1895, in Morrilton, Ark., Mr. Rice was a 32-year veteran with Commonwealth Edison, having joined the utility in 1917. After serving as Chief Operator, he became Supervisor of the Operating Division in the Substation Department in 1927. Two years later, he was transferred to the Maintenance Division, acting in a similar capacity, and, in 1935, he was designated Assistant Engineer of Maintenance.

MEMBERSHIP . . .

Recommended for Transfer

The board of examiners at its meeting of October 27, 1949, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Allen, A. J., meter engineer, Consolidated Edison Co., of N. Y., Inc., New York, N. Y.
Barrett, W. J., electrical co-ordination engineer, N. J. Bell Tel. Co., Newark, N. J.
Cox, V. L., mgr. of engg., switchgear divs., General Electric Co., Phila., Pa.
DeMeris, M., chief power engineer, Tennessee Valley Authority, Chattanooga, Tenn.
Ferrill, R. M., system planning engineer, Tennessee Valley Authority, Chattanooga, Tenn.
Gary, L. R., manager, engineering dept., Philadelphia Electric Co., Phila., Pa.
Harper, J. D., asst. district power mgr., Aluminum Co. of America, Alcoa, Tenn.
Hill, W. S., vice-pres., engg., Locke Inc., Baltimore, Md.
Kendrick, W. H., vice-pres., chg. of operations, South Carolina Elec. & Gas Co., Columbia, S. C.
McCann, G. D., elec. engg. professor, California Institute of Technology, Pasadena, Calif.
Wolff, S. S., chief engr., Century Electric Co., St. Louis, Mo.

11 to grade of Fellow

To Grade of Member

Askew, J. D., radio engr., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Basinger, C. B., graduate student, Univ. of Michigan, Farma, Mich.
Belsky, P., consulting & application engr., Westinghouse Elec. Corp., Los Angeles, Calif.
Bertolet, E. C., electronics engr., seismic geophysical instrument lab., The Superior Oil Co., South Pasadena, Calif.
Bradshaw, R. C., small motor design engr., Westinghouse Electric Corp., Lima, Ohio
Cade, P. J., chief engr., Photorwitch, Inc., Cambridge, Mass.
Carroll, F. W., asst. head, acquisition section, Rural Electrification Adm., Washington, D. C.
Cooper, E. A., partner, Brink-Dunwoody-Cooper, Iola, Kans.
Degnan, W. J., elec. engr., high voltage engg. lab., General Electric Co., Pittsfield, Mass.
de Lascurain, M. M., consulting engr., Lascurain & Mier, Co., Mexico, Federal District, Mexico
Dodson, V. E., asst. to district mgr., Pacific district, General Electric Co., San Francisco, Calif.
Drummond, V. L., supervisor, plant engg. section, Chevrolet-Central Office, GMC., Detroit, Mich.
Dupree, G. W., elec. engr., operating dept., Southwestern Public Service Co., Amarillo, Tex.
Elvove, E., consulting engr.; partner, Semco Services, New York, N. Y.
Frank, J. M., elec. engr., Hevi Duty Electric Co., Milwaukee, Wis.
Gerhold, R. A., electronics engr., material lab., N. Y. Naval Shipyard, Brooklyn, N. Y.
Gerlicher, T. O., supervising design engr., Headman-Ferguson & Carollo, Emeryville, Calif.
Grafinger, L. N., research engr., servomechanisms lab., Massachusetts Institute of Technology, Cambridge, Mass.
Hammer, O. S. C., elec. engr. IV, Tennessee Valley Authority, Chattanooga, Tenn.
Heffelfinger, J. B., consulting radio engr., Kansas City, Mo.
Hemperly, J. H., senior elec. engr., General Electric Co., Richland, Wash.
Humber, J. H., design & research engr., eclipse-pioneer div., Bendix Aviation Corp., Teterboro, N. J.
Johnson, E. L., elec. engr., The Connecticut Power Co., New London, Conn.
Johnson, G. S., electric plant engg. dept., Kohler Co., Kohler, Wis.
Jones, L. G., layout draftsman, The Glenn L. Martin Co., Baltimore, Md.
Lewin, W. A., supt., electrical installations, General Electric Co., Chicago, Ill.
Lewis, C. B., section engr., control engg. div., General Electric Co., Erie, Pa.
Lloyd, H. R., Jr., application engr., General Electric Co., Schenectady, N. Y.
Long, A. S., mgr., transmission-record communication, International Standard Electric Corp., New York, N. Y.
Lyons, S. E., electrical engr., Tennessee Valley Authority, Chattanooga, Tenn.
McClarren, A. E., asst. electrical engr., Electric Boat Co., Groton, Conn.
Miller, A. A., relay foreman, Buffalo Niagara Electric Corp., Buffalo, N. Y.
Morris, W. C., Jr., asst. supt., meter & service depts., Southwestern Gas & Electric Co., Shreveport, La.
Parchman, J. B., engr., Texas Power & Light Co., Dallas, Tex.
Parent, R. J., asst. prof., electrical engg., Univ. of Wisconsin, Madison, Wis.
Potts, H. M., elec. engr.; chief, marketing & sales div., U. S. Bureau of Reclamation, Boise, Idaho
Qurollo, J. J., Jr., engr., Western United Gas & Electric Co., Aurora, Ill.
Rademeyer, H. P., elec. engr., Monsanto Chemical Co., St. Louis, Mo.
Raushenberger, E. J., elec. engr., Rural Electrification Adm., Washington, D. C.
Rhea, T. R., mgr., chem. & pet. div., General Electric Co., Schenectady, N. Y.
Rice, B. S., load supervisor, engg. dept., Buffalo Niagara Elec. Corp., Buffalo, N. Y.
Richardson, H. C., asst. supt. of operations, northern div., Duquesne Light Co., Pittsburgh, Pa.
Richmond, J. K., assoc. lab. engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Sale, H. C., chief electrical inspector, City of New Orleans, New Orleans, La.
Sayner, W. V., area budget control supervisor, American Tel. & Tel. Co., Chicago, Ill.
Scott, F. M., engineer, electrical dept., Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Scott, J. M., Jr., sales engr., Westinghouse Elec. International Co., New York, N. Y.
Skyllingstad, D. E., district engr., The Kerite Co., Chicago, Ill.
Smith, F. R., elec. engr., Gulf States Utilities Co., Beaumont, Tex.
Smith, R., chief electrical engr., Mead Corp., Chillicothe, Ohio
Storrs, G.S., layout designer, Glenn L. Martin Co., Baltimore, Md.
Stuart, J. F., elec. engr., El Paso Electric Co., El Paso, Tex.
Taylor, J. B., asst. vice-pres., Atlantic City Elec. Co., Atlantic City, N. J.
Vance, P. A., section engr., General Electric Co., Ft. Wayne, Ind.
Wald, F. O., meter supt., Utah Power & Light Co., Salt Lake City, Utah
Weber, J. C., assoc. prof. of elec. engg., Univ. of Wisconsin, Madison, Wis.
Wells, C. H., chg. pulse transformer design, General Elec. Co., Pittsfield, Mass.
West, O. W., elec. engr., Western Electric Co., Chicago, Ill.
Wirt, J. R., welding engr., process dept., Delco Remy Div., GMC., Anderson, Ind.

59 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member have been received from the following candidates, and any member objecting to election should so notify the Secretary before December 25, 1949, or February 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Haldane, T. G. N., Mers & McLellan, Milburn, Esher Surrey, England
Levi, G., Dr., Palestine Elec. Corp. Ltd., Haifa, Israel

2 to grade of Fellow

To Grade of Member

Abell, S. E., Ohio Public Service Co., Sandusky, Ohio
Albert, E. K., California-Pacific Utilities Co., San Francisco, Calif.
Auer, R. W., 50 E. 67th St., New York, N. Y.
Berges, D. M., Pesco Products, Cleveland, Ohio
Boerner, T. J., RCA Victor Div., Camden, N. J.
Campbell, J. H., General Elec. Co., Cleveland, Ohio
Cavanagh, J. G., Iowa Power & Light Co., Des Moines, Iowa
Chadwick, J. H., The Alabama Polytech. Inst., Auburn, Ala.
Clayton, M. D., Univ. of Connecticut, Storrs, Conn.
Coleman, I. V., Automatic Elec. Co., Chicago, Ill.
Fels, G. B., Patterson Elec. (Eastern) Ltd., Montreal, Quebec, Canada
Fish, J. P. (re-election), Gonzalo Puyat & Sons, Inc., Manila, P. I.
Forsyth, J. C., Municipal Electricity Dept., Christchurch, New Zealand
Furst, J. J., Sperry Gyroscope Co., Great Neck, N. Y.
Gilbert, E. A., Radio Frequency Labs., Inc., Boonton, N. J.
Grate, H. W., Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Guse, R. C., The Washington Water & Power Co., Spokane, Wash.
Hall, N. L., Hughes Aircraft Co., Culver City, Calif.
Hamilton, J. T. (re-election), Baker & Co., Newark, N. J.
Hartman, J. R., American Locomotive Co., Schenectady, N. Y.
Hewson, C. R., General Elec. Co., Boston, Mass.
Hibbard, L. J. (re-election), Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Howe, J. F., General Motors Corp., Dayton, Ohio
Jacobs, R. S., 2176 St. Catherine St., W., Montreal, Quebec, Canada
Johns, J. P., Southwest Tenn. EMC, Brownsville, Tenn.
Johnson, L. D., Sangamo Elec. Co., Springfield, Ill.
McCreery, R. L., Bureau of Reclamation, Washington, D. C.
McCutchen, J. M., Rural Electrification Admin., Washington, D. C.
McPherson, J. G., I. B. M., New York, N. Y.
Mandeno, L., P. O. Box 1277, Auckland, New Zealand
Morrison, A. T., Electro Switch Corp., Weymouth, Mass.
Ostendorf, B., Bell Tel. Labs., New York, N. Y.
Poole, H. W., General Elec. Co., Schenectady, N. Y.
Reist, J., Power Corp. of Canada, Montreal, Quebec, Canada
Roper, V. J., General Elec. Co., Cleveland, Ohio
Seibert, R. M., Stromberg-Carlson Co., Rochester, N. Y.
Springer, H. E., Rayonier, Inc., Fort Angeles, Wash.
Stacey, E. M., General Elec. Co., Schenectady, N. Y.
Stainton, H. M., Florida Power & Light Co., Miami, Fla.
Stevens, J. H., Canada Wire & Cable Co., Leaside, Ontario, Canada
Tall, M. A., Phillips Packing Co. Inc., Cambridge, Md.
Taylor, T. A. I. C., Patterson Elec. Ltd., Montreal, Quebec, Canada
Thayer, A. H., Dept. of Water & Power, Los Angeles, Calif.
Tomasso, M. C., General Elec. Co., Philadelphia, Pa.
Toy, E. L., Canadian General Elec. Co., Ltd., Toronto, Ontario, Canada
Troster, M., Otis Elevator Co., New York, N. Y.
Weems, F. C., Southern Bell Tel. & Tel. Co., Jackson, Miss.
Woodruff, C. S., Ogden & Woodruff, Baton Rouge, La.
Zwingli, C. T., American Agricultural Chemical Co., New York, N. Y.

49 to grade of Member

OF CURRENT INTEREST

Exploratory Meeting Discusses Increased Unity for Engineers

For some time Engineers Joint Council has been studying suggestions which have been made from various sources as to means by which the engineering organizations of the United States could co-operate in increasing the unity of the engineering profession. These studies led to an invitation sent this past summer by Engineers Joint Council to 16 of the leading engineering societies of the country, suggesting that each society designate a representative to take part in an exploratory meeting to discuss further this very important subject.

This meeting was held on October 20, 1949, under the chairmanship of R. E. Dougherty, EJC Chairman. Representatives of 14 of the 16 societies were present. H. S. Osborne was made secretary of the meeting.

There was a very full and free discussion of the whole problem.

Agreement was general among the members of the group that some steps toward organizing for increased unity of the engineering profession would be desirable. If an organization is to speak for the profession in important public matters and in other questions which affect the profession as a whole, it should have a structure which would enable it to respond to the various services which it may perform. No conclusion was reached as to the form which such structure might take. However, the group felt that the first approach to this subject would best be made through considering methods for closer co-operation between the existing organizations and for modifying, and perhaps grouping, some of these organizations rather than to consider the establishment of an entirely new additional organization.

As a result of the discussion a Planning Committee was appointed from members of the group, charged with the responsibility for preparing statements regarding various alternative plans of achieving this aim and reporting back to the main group. The date of the next meeting of the main group was set tentatively for January 27, 1950.

(*Editor's Note:* For background material and the steps which have been taken by the AIEE toward increased unity of the engineering profession, see the summary report of the Professional Activities Subcommittee of the Committee on Planning and Co-ordination on Organization of the Engineering Profession published in *Electrical Engineering*, May 1947, pages 496–501. This report and the ways to achieve professional unity are discussed in an address by President James F. Fairman, "Can Engineers Be Synchronized?", published in *Electrical Engineering*, September 1949, pages 749–50.)

Representatives who attended the meeting of the exploratory group, were as follows:

American Association of Engineers: James H. Griffin, Board of Transportation of the City of New York, N. Y.

American Institute of Chemical Engineers: L. W. Bass, U. S. Industrial Chemicals, Inc., New York, N. Y.

American Institute of Electrical Engineers: T. G. LeClair (F '40), Commonwealth Edison Company, Chicago, Ill.

American Institute of Mining and Metallurgical Engineers: James L. Head, Anaconda Copper Company, New York, N. Y.

American Society of Civil Engineers: Carlton S. Proctor, New York, N. Y.

American Society for Engineering Education: Dean Thorndike Saville, College of Engineering, New York University, New York, N. Y.

The American Society of Mechanical Engineers: Edgar J. Kates, New York, N. Y.

American Society of Refrigeration Engineers: Professor Burgess H. Jennings (*part-time*), Mechanical Engineering Department, Northwestern University, Evanston, Ill.
Professor C. F. Kayan (*alternate*), Columbia University, New York, N. Y.

American Water Works Association: Harry E. Jordan, American Water Works Association, New York, N. Y.

Institute of Aeronautical Sciences: S. Paul Johnson, Director, Institute of Aeronautical Sciences, New York, N. Y.

Institute of Radio Engineers: B. E. Shackelford, RCA International Division, New York, N. Y.

National Society of Professional Engineers: Alex Van Praag, Jr., Warren and Van Praag, Inc., Decatur, Ill.

Society of Automotive Engineers: Hollister Moore (*alternate for W. S. James*), Manager, Membership and Sections Department, Society of Automotive Engineers, New York, N. Y.

Society of Naval Architects and Marine Engineers: J. H. King (*part-time*), care of Babcock and Wilcox, New York, N. Y.
Captain W.N. Landers (*alternate*), Secretary, Society of Naval Architects and Marine Engineers, New York, N. Y.

The following representatives were absent:

American Society of Heating and Ventilating Engineers: Dean L. E. Seeley, University of New Hampshire, Durham, N. H.

Illuminating Engineering Society: Lee E. Taylor, Detroit Edison Company, Detroit, Mich.

The following members were appointed to the exploratory group's Planning Committee:

B. E. Shackelford, *Chairman;* L. W. Bass, E. J. Kates, T. G. LeClair, Dean Thorndike Saville, Alex Van Praag, Jr.; also, R. E. Dougherty, New York Central System, New York, N. Y., *ex-officio;* and H. S. Osborne, New York, N. Y., *Secretary*

AIEE New York Section Plans Joint Sessions at AAAS Meeting

The AIEE New York Section will be sponsor of a 3-day joint session to be held at the 116th Annual Meeting of the American Association for the Advancement of Science in New York, N. Y., December 26–31, 1949 (*EE, Nov '49, p 1014*). The subject of the sessions will be "Television."

A symposium, in two parts, is to be held at the Hotel McAlpin. The first part, on Wednesday evening, December 28, will cover "The Technology of Television" and will be conducted by John V. L. Hogan (M '20) of Hogan Laboratories, Inc., New York, N. Y. Taking part with Mr. Hogan in dealing with the various phases of the subject will be the following:

John H. Roe, Supervisor, Television Engineering Group, Engineering Products Department, RCA Victor Division, Radio Corporation of America

R. M. Bowie, Manager, Physics Laboratory, Sylvania Electric Products, Inc.

T. T. Goldsmith, Jr., Director of Research, Allen B. DuMont Laboratories, Inc.

The second part of the symposium will be held on the evening of December 29 and will cover "The Impact of Television on Society," and "Future Developments." W. L. Laurence, Science Reporter for *The New York Times*, will be in charge of this session. Taking part also will be

Sterling W. Fisher, Manager of Public Affairs and Education Department, National Broadcasting Company

Ricardo Muniz, General Manager, Receiver Division, Allen B. DuMont Laboratories, Inc.

E. Finley Carter (M '47) Vice-President in Charge of Engineering, Sylvania Products, Inc.

In addition to the symposium, the AIEE is preparing an exhibit illustrating the principles of operation of the various elements involved in bringing television from the studio to the home. This exhibit, which will include working models, kinescope recordings, and other items of interest, will be held in the East Room at the Hotel McAlpin and will be open December 28, 29, and 30.

Reclamation Bureau to Transmit Power Via Cable in Tunnel

Power for the operation of the Granby pumping plant on the Colorado–Big Thompson project will be transmitted via cable through the Alva B. Adams irrigation tunnel under the Continental Divide. The Commissioner of Reclamation has authorized an award of contract to Electrical Constructors, Inc., and C. M. Elliott, Chula Vista, Calif., on a low bid of $986,000.

The decision to transmit power in this unprecedented manner rather than by stringing a high-voltage transmission line over the rugged Rocky Mountain country was on the recommendation of the Chief Engineer and Regional Director of the Bureau at Denver. It will eliminate the necessity of erecting and maintaining a tower transmission line across one of the highest and most rugged sections of the Rocky Mountains. There is a calculated risk involved in that any emergency maintenance of the cable might require stopping the flow of water through the tunnel, but technicians after full study report that this risk is no greater than that in maintaining a tower transmission line through the almost inaccessible area which is swept by bitter cold storms every winter.

The Commissioner of Reclamation esti-

mates savings of approximately $500,000 by placing the cable in the tunnel. The low bid of $986,000 for this job of running a 69-kv transmission circuit through the tunnel compared with a low bid for the tower line of $1,483,782.66.

The cable will be contained in a gas-filled pipe to keep out moisture and will be strung along the ceiling of the 9½-foot-diameter 13-mile-long tunnel. The tunnel cuts under the Continental Divide running more than 3,600 feet below some of the high peaks towering above it. It will present a unique situation. Water from the west slope of the Rockies will be diverted through the tunnel to plunge through hydroelectric plants on the east slope. A portion of the power generated there will be returned through the tunnel via the transmission lines to pump more water eastward through the tunnel.

Placing of the tunnel transmission cable will not interfere with the present operation of the tunnel. The tunnel is now used only during the irrigation season and the transmission cable will be strung before the project plan can be fully effectuated by operation of the Granby pumping plant. This plant is now under construction and a fully sustained pumping program is planned by 1953.

Credit Balance, Photoprint Service, Cited in Report of Engineering Societies Library

According to the Annual Report of the Director of the Library, the Engineering Societies Library ended its 36th fiscal year last September 30 with a credit balance for the first time in several years. Also noted in the report was the development of a new photoprint service, installation of shelving, and discarding of some library material.

The annual report discussed a survey made by Richardson Wood, which was primarily a study of library services, but which dealt also with collection and space problems. The survey was financed by a $5,000 grant from the Engineering Foundation and was supervised by the Library Study Committee under Chairman Ole Singstad.

Those who made the survey came up with three recommendations for improving library procedure. One of these has been modified and adopted for a trial period. It calls for the supplying of photoprint copies of not only material that is available at the Engineering Societies Library, but of technical articles that are available anywhere in the United States. This expanded service has just been announced.

Statistics given in the library's report show a reduction in the number of paid services, but an increase in the number of persons visiting the library over the previous fiscal year.

Because the Founder Societies decided to make their allotments to the library, on the basis of their membership, three months, instead of 15 months, before the beginning of the fiscal year, the library derived an unanticipated increase in income of over $2,200. Moreover, contributions from other organizations and income from sale of books and periodicals were over $1,300 greater than expected. Expenditures were less than estimated, largely because two staff members who resigned were not replaced. And for the first time in several years, costs of operation did not rise faster than income. All of this contributed to obtaining a small credit balance. Greater efficiency, less turnover, and fewer books to be catalogued made it possible to absorb the loss of two workers.

During the fiscal year, the staff prepared brief reviews of 514 books valued at over $2,600. These reviews are published in the journals of the four Founder Societies, in the Journal of the Engineering Institute of Canada, and by the Engineering Index.

In the Engineering Societies Building, space was provided for an additional 12,000 library volumes. In the reading room, several offices and walls have been painted. Glass troughs have been removed from the lighting fixtures. As a result readers now have a light intensity of 20 foot-candles.

Many valuable gifts of books and periodicals were received by the library in the past year. Outstanding among these was the collection of books on precious stone bequeathed to the library by Sydney H. Ball. There are some 400 volumes dating from 1548.

Future Meetings of Other Societies

American Association for the Advancement of Science. 116th Annual Meeting. December 26–31, 1949, Hotels Statler, Governor Clinton, New Yorker, McAlpin, and Martinique, New York, N. Y.

American Institute of Chemical Engineers. National Meeting. December 4–7, 1949, William Penn Hotel, Pittsburgh, Pa.

American Meteorological Society. 30th Anniversary Meeting. January 3–6, 1950, St. Louis, Mo.

American Society of Mechanical Engineers-Society for the Advancement of Management. Plant Maintenance Show. January 16–19, 1950, The Auditorium, Cleveland, Ohio

American Society for Testing Materials. February 27–March 2, 1950. William Penn Hotel, Pittsburgh, Pa.

Armed Forces Communications Association. 1950 Annual Meeting. April 26–27, 1950, New York, N. Y.; April 28, 1950, Fort Monmouth, N. J.

Atomic Energy Commission–New York University. Conference on Industrial and Safety Problems of Nuclear Technology. January 10-12, 1950, New York University, New York, N. Y.

Institute of the Aeronautical Sciences. 18th Annual Meeting. January 23–26, 1950, Hotel Astor, New York, N. Y.

Institute of Radio Engineers. Second Southwestern Conference. December 9–10, 1949, Baker Hotel, Dallas, Tex.

National Electrical Manufacturers Association. March 13–16, 1950, Edgewater Beach Hotel, Chicago, Ill.

National Petroleum Association. April 12–14, 1950, Hotel Cleveland, Cleveland, Ohio

National Society of Professional Engineers. 1949 Annual Meeting. December 8–10, 1949, Houston, Tex.

Protective Relay Engineers. Third Annual Conference. March 20–22, 1950, Department of Electrical Engineering, Agricultural and Mechanical College of Texas, College Station, Tex.

Society of Automotive Engineers. January 9–13, 1950, Hotel Book-Cadillac, Detroit, Mich.

AEC–NYU Meeting to Deal With Safety in Nuclear Technology

New York University in co-operation with the Atomic Energy Commission will hold for the first time next January a 3-day conference on Industrial and Safety Problems of Nuclear Technology.

Scheduled to be conducted January 10, 11, and 12 at New York University, the conference will be the first of its kind in the area of industrial applications of nuclear technology. It will be sponsored by the university's adult branch, the Division of General Education, and the university's Center for Safety Education. The conference was planned by Assistant Professor Sidney G. Roth, director of technical courses at the division, and Dr. Walter Cutter of the Safety Center.

The conference, according to Professor Roth, will attempt to meet the needs of industrial firms as well as technicians who want to know more about how atomic energy can be applied to peacetime uses.

The first day's discussion will be concerned with problems created by the production of radioactive materials with special emphasis on hazards associated with radiation. The use of isotopes and the requirements of a radio-chemical laboratory for safe handling of isotopes will be considered on the second day.

The third and final day of the conference will be devoted to such questions of public health as water pollution and sewage disposal, which might arise from the establishment of radio-chemical laboratories and Atomic Energy Commission installations. Important questions of insurance will also be discussed by leading investigators in the field.

Among the speakers who will participate in the 3-day conference are Gordon Dean, one of the five commissioners of the Atomic Energy Commission; W. E. Kelley, manager of the New York Operations Office of the AEC; Dr. G. K. Green, chief of the Accelerator Project at the AEC's Brookhaven National Laboratory; Dr. Serge A. Korff, Professor of Physics at New York University; and Dr. G. Failla, Professor of Radiology at Columbia University.

Franklin Institute Appointments. Dr. Nicol H. Smith has been named Director of Research Operations of the Franklin Institute Laboratories for Research and Development, Philadelphia, Pa. With the Franklin Institute since 1932, Dr. Smith is noted for his technical work on the atomic weight of scandium and for his researches on germanium, tungsten, and magnesium oxychloride elements. Last year, he was awarded the Presidential Certificate of Merit for his services in the field of ballistic research with the Office of Scientific Research and Development. Other new appointments at the Franklin Institute laboratories are: Ralph H. McClarren to Associate Director for Electronics and Instruments; Frank S. Chaplin to Associate Director for Mechanical and Civil Engineering; Harry H. Stout, Jr., to Assistant Director for Contract Administration; and Peter F. Suffredini to Manager of Administrative Services.

"Aircomatic" Welding Process

Welding aluminum plate in any position is possible with this newly developed "Aircomatic" welding gun. There are no electrodes to change and the filler metal is fed to the gun automatically from the spool at the right. Argon or helium gas, also fed to the gun, shields the molten metal from air and eliminates the need for fluxes, electrode coatings, and slag removal. The process was developed by the Air Reduction Sales Company and at the Battelle Institute

Meagher Elected President of United Engineering Trustees

Edward C. Meagher, Treasurer, Texas Gulf Sulphur Company, New York, was re-elected President of the United Engineering Trustees, Inc., at its recent annual meeting in the Engineering Societies Building, New York, N. Y.

Other officers re-elected were: Irving V. A. Huie (American Society of Civil Engineers), President of the Board of Water Supply, New York, and James F. Fairman (President AIEE), Vice-President of the Consolidated Edison Company of New York, as Vice-Presidents; Kurt W. Jappe, retired Director of Purchases, Hercules Powder Company, Wilmington, Del., and Treasurer of The American Society of Mechanical Engineers, as Treasurer; James L. Head (American Institute of Mining and Metallurgical Engineers), Department of Mines, Chile Exploration Company, New York, as Assistant Treasurer. John H. R. Arms (American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers), was re-elected Secretary.

Colonel William N. Carey, Secretary of the American Society of Civil Engineers, will head the Real Estate Committee, which includes Messrs. James L. Head, Warner Seely, and A. G. Oehler. George W. Burpee (American Society of Civil Engineers), will serve as Chairman of the Finance Committee. Other members will be Messrs. K. W. Jappe, James L. Head, R. F. Gagg, and D. A. Quarles (F '41).

United Engineering Trustees, Inc. is a corporation set up jointly by the four national engineering Founder Societies, which have an aggregate membership of about 100,000. These societies are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers and American Institute of Electrical Engineers.

The corporation promotes the advancement of the engineering arts and sciences in all their branches, through two departments, the Engineering Foundation and the Engineering Societies Library. The corporation is the titular owner of the Engineering Societies Building and of the trust funds of the Library, the Foundation, the John Fritz Medal Board of Award, and the Daniel Guggenheim Medal Board of Award.

Physical Science Internships Offered to Students by NBS

Excellent opportunities now exist for outstanding students in science and engineering to broaden their undergraduate or graduate training through vacation-time employment and graduate fellowships offered by the National Bureau of Standards. The Bureau has established an integrated work-study program, beginning at the college-sophomore level, for the selection and training of its research scientists and engineers. This program permits the student to alternate periods of full-time study with actual work experience in his chosen field, supplemented by on-the-job training and orientation courses at the Bureau. At the same time it enables the Bureau to select promising students, upon graduation, for permanent appointment to its staff and to provide them with opportunities for professional growth and advancement through further in-service training.

As the principal agency of the Federal Government for fundamental research in physics, mathematics, chemistry, and engineering, the National Bureau of Standards carries on a wide variety of projects ranging all the way from measurement of the magnetic moment of the proton to the development of new types of materials for prefabricated housing. Work in these fields at the Bureau includes basic and applied research, development, testing, calibration, and scientific advisory services. This diversity permits the student to choose work in his particular field of interest and to broaden his experience through contact with other related lines of work at the Bureau.

There are essentially three programs of interest to college and university students: the internship program for undergraduates; the regular training program for college graduates on the staff; and the fellowship program for graduates engaged in working for advanced degrees.

For the college undergraduate, there is a work-study program leading to permanent appointment as a professional member of the Bureau staff. Students who have completed at least two years of an engineering or science course are appointed under this plan as Student Aids on the basis of a test of general ability, which also qualifies them for permanent professional appointment after graduation. Those who have credit for two years of college receive a salary of $208 per month while those who have finished their junior year are paid $227 a month. Usually appointments are for a 3-month period during the summer vacation. However, if greater work experience is desired than can be obtained in one or two summers, the last two or three years of the college course may be spent in alternate periods of work and study under the cooperative plan of education offered by a number of technical schools in this country.

Upon full-time appointment to the Bureau's professional staff, the young scientist or engineer is given an indoctrination course consisting of two hours a week for 15 weeks. This training program includes instruction in technical skills necessary for performing one's job at the Bureau and the developing of habits of work, study, and thinking that will be of advantage in tackling research problems.

Regarding the graduate study program, the Bureau of Standards has made available a limited number of research fellowships. These positions, which require no examination, may be filled by graduate students, provided the work to be done is useful in fulfilling the thesis requirement for an advanced degree. The stipend is $2,974 a year.

Further information regarding study programs and qualifications for appointment may be obtained from the Personnel Division, National Bureau of Standards, Washington 25, D. C.

University and Industrial Research. Two conferences on research, one dealing with university work and the other slanted to researchers in industry, were held recently. The former, which was held in mid-September at the Pennsylvania State College, State College, Pa., had as its theme, "The Functions of University Research." Titled the Third Annual Conference on the Administration of Research, the 3-day meeting explored the relationship between the

university and government and industry. One of the many topics discussed was the present methods of supporting university research. At the South Dakota School of Mines and Technology, Rapid City, S. Dak., a 2-day Conference (October 20–21) on Industrial Research took place. The role of research in the mineral, chemical, hydraulic, electrical, and mechanical industries and in agriculture was discussed.

Engineering Foundation Elects Bakhmeteff Head, Aids Research

The Engineering Foundation elected Dr. Boris A. Bakhmeteff, Consulting Engineer and Professor of Civil Engineering, Columbia University, its Chairman at the recent annual meeting of its Board in the Engineering Societies Building, New York, N. Y. Dr. C. G. Suits (F'47) of the General Electric Company was chosen Vice-Chairman. Re-elected officers included Frank T. Sisco as Technical Director, and John H. R. Arms as Secretary.

Dr. Bakhmeteff was also appointed Chairman of the Executive Committee. Other members of the Executive Committee are: Mr. Arms as Secretary; Dr. Suits; Dr. A. B. Kinzel, Vice-President of the Union Carbide and Carbon Research Laboratories, Inc.; Herman Weisberg (American Society of Mechanical Engineers), Mechanical Engineer in the Electrical Engineering Department of the Public Service Company of New Jersey; and D. A. Quarles (F'41), Vice-President of the Bell Telephone Laboratories, Inc.

The Research Procedure Committee will be headed by Dr. Bakhmeteff. Other members are: E. R. Kaiser (American Institute of Mining and Metallurgical Engineers), Assistant Director of Research, Bituminous Coal Research Inc., Pittsburgh, Pa.; Herman Weisberg (American Society of Mechanical Engineers); and Dr. Suits.

Reports were made at the meeting on 14 research projects sponsored and supported in part by Engineering Foundation during the past year. These projects, for the support of which nearly $500,000 was contributed by the Foundation and by industry, included research in such varied fields as the properties of riveted and bolted structures for bridges, properties of steel at various temperatures, as well as properties of reinforced concrete for building construction, welding, and lubrication.

Grants were recommended for the year 1949–1950 for the continuation of ten of the past year's 14 projects and for the support of five new projects. Among the important new researches being undertaken with Foundation sponsorship and grants are the internal rusting of water pipes, the performance of power plant furnaces, and increased efficiency in building small homes.

The Engineering Foundation, a department of United Engineering Trustees, Inc., has now been engaged in important research activities for more than 35 years. It aided in establishing the National Research Council and its division of Engineering and Industrial Research. It has contributed to the support of the Engineers' Council for Professional Development, which, representing eight organizations, aims at the advancement of the profession of engineering.

Engineering Societies Library Offers Comprehensive Photoprint Service

Under a new service offered by the Engineering Societies Library, readers of this magazine may obtain photoprint copies of technical articles available anywhere in the United States. Heretofore, photoprints only of material contained in the library were supplied.

The applicant has the option of using either the new "comprehensive service" or the old "limited service."

If an individual or organization decides to use the "comprehensive service," then he must sign an agreement to accept conditions and rates of the "comprehensive service" plan as the basis for *all* photoprint orders placed by him with the Engineering Societies Library from the date of the agreement through December 31, 1950. Until that date, the new plan is being operated on a trial basis. Should it prove practicable, then the "comprehensive service" will be continued, and all agreements with the library may be renewed. Copies of the agreement forms may be obtained from the Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

Photoprints of technical material, under the comprehensive plan, are available at a flat rate of five dollars per article, if the article is not over 25 pages. For longer articles, there is a charge $2.50 for each additional 25 pages or fraction thereof. Members of the AIEE or any other of the Founder Societies who order photoprints for their personal use will be charged $4.50 for the first 25 pages and $2 for each succeeding 25 pages.

If the reader does not wish to avail himself of the new plan, then he may use "limited service" for obtaining photoprints. Under this procedure, only material contained in the library is copied, and, as in the past, no signed agreement is required. Photoprints will be supplied at 40 cents per print—minimum charge, $1 per order. Any two facing pages that together measure not over 11 by 14 inches can be taken on one print. Larger material requires one print per page. For AIEE members, the charge for "limited service" is 35 cents per print.

Photoprints are white-on-black (negative) prints. Copyrighted material will not be copied beyond recognized "fair use" without the signed authorization of the copyright owner. All responsibility for questions of copyright that may arise in the copying and in the use made of the copies must be assumed by the applicant.

Rates are subject to change without notice, except that no increase will be made without notifying those having agreements for the use of the "comprehensive service."

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electromagnetic Induction

To the Editor:

George I. Cohn (*EE, Nov '49, pp 1018–19*) in discussing induction in a Faraday disk when the flux is pulsating, concludes that: the flux linking law gives wrong results; the flux cutting law gives the correct result; and experiment verifies his conclusion. I submit that Cohn is completely wrong on all three counts! Referring to Figure 1 there is shown on the left, part *A*, a solid rotating disk, through which a uniform flux of density $B_0 \cos \omega' t$ is pulsating. Select any radius oc and then complete the circuit $oaMbco$ through external brushes a and b and meter M. Now it is impossible for the meter M to register all the voltage induced, because that part of the induced voltage due to the *pulsation* of the flux will induce eddy currents in the solid material of the disk just sufficient to consume that component of the induced voltage. In order to avoid worrying about these eddy currents, and in order that the meter may measure the *total* induced voltage, suppose we replace the solid disk by a single-spoke wheel as shown in part *B*. (A solid disk may be thought of as an infinitely multiple spoke wheel.) It will be expedient to cut the rim of this single-spoke wheel at some point, for otherwise the eddy currents will flow around the rim. This simplification does not in any way vitiate the principles under consideration. Now doing just as Cohn did we have

$$\varphi = \frac{R^2\theta}{2} B_0 \cos \omega' t = \text{flux linking circuit } oaMbco$$

$$\theta = \omega t = \text{angle swept out by } oc$$

$$\frac{d\varphi}{dt} = \frac{R^2 B_0}{2}\left(\frac{d\theta}{dt} \cos \omega' t - \omega' \theta \sin \omega' t\right) \qquad (1a)$$

$$= \frac{R^2 B_0}{2}(\omega \cos \omega' t - \omega' \omega t \sin \omega' t) \qquad (1b)$$

$$= \frac{R^2 B_0}{2} \omega (\cos \omega' t - \omega' t \sin \omega' t) \qquad (1c)$$

The $\cos \omega' t$ term may be interpreted as "flux cutting action." The $\sin \omega' t$ may be interpreted as "transformer action." Cohn said that this complete expression "is obviously incorrect for $t \to \infty$ as $t \to \infty$." He then said,

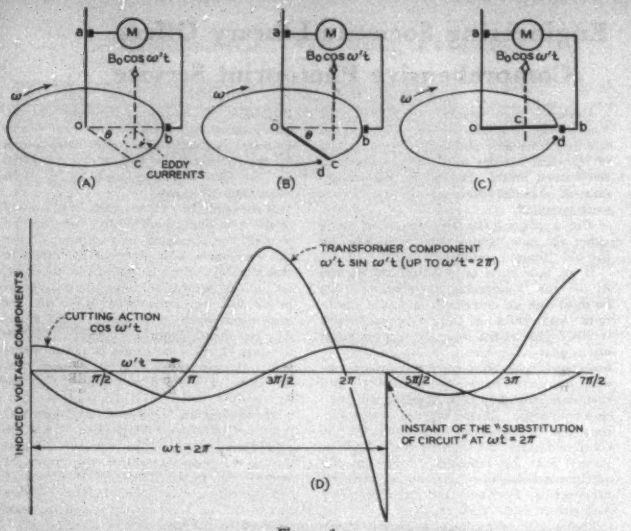


Figure 1

A—Solid disk
B—Single spoke and interrupted ring
C—"Substitution of circuit" at $\omega t = 2\pi$
D—Plot of induced voltage components

"As may easily be verified by experiment the correct result is ... (the cos $\omega' t$ term)." Actually, the *complete expression* gives the total induced voltage *up until the time* $\omega t = 2\pi$, at which time a "substitution of circuit" takes place as the spoke passes the brush b, as shown in part *C* of Figure 1 (at which instant the circuit *oaMbc* is "substituted" for the circuit *oaMbdc* as the brush breaks contact with point *d* and makes contact with point *c*). At this instant when *cd* passes the brush the transformer induced voltage ($\omega' t \sin \omega' t$) drops to zero, and starts over from zero. A plot of the induced voltage components is shown in Figure 1*D*.

The foregoing fixes attention on a particular spoke of the wheel, and shows how the induced voltage in the circuit of which that spoke is a part, consists of two components of voltage—the cos $\omega' t$ term due to cutting action, and the $\omega' t \sin \omega' t$ (up to $\omega t = 2\pi$) due to transformer action. It clearly shows a substitution of circuit as the spoke passes the brush.

Now as an alternative point of view let us fix our attention on a (fixed in space) radial line from the center of the disk out to the brush b, and calculate the voltage induced in the circuit of which this radial line is a part. Once again, in order to avoid eddy currents, let our disk be replaced by a wheel with numerous spokes, and a rim interrupted between every spoke, as shown in Figure 2. Take the brush b at some angle θ from the reference line ob' (parallel to aM). In this case θ is a constant (*not* equal to ωt), but the instantaneous angular velocity of the spoke oc is $d\theta/dt = \omega$. Hence equation 1a becomes

$$\frac{d\varphi}{dt} = \frac{R^2 B_0}{2}(\omega \cos \omega' t - \omega' \theta \sin \omega' t)$$

in which the cos $\omega' t$ is due to cutting action and the $\theta \sin \omega' t$ term is due to transformer action. Now this latter term is greater the greater θ, but repeats after $\theta = 2\pi$. Thus a different induced voltage is experienced for every position of the brush. In particular, for $\theta = 0$, the brush is at b' and only the motional term of induced voltage survives. Once again, we observe a "substitution of circuit" as each spoke in succession takes up and passes through the position oc.

We must conclude, therefore, that for either point of view (Figure 1 or Figure 2), there exists, *in general*, both motional and transformer components of induced voltage in the Faraday disk. It is only in the particular case $\theta = 0$ in Figure 2 that only a motional component survives.

This example, of Cohn's own choosing, shows how badly he has gone astray in his reasoning. First, he ignores completely the transformer component of induced voltage. Second, his denial of the "substitution of circuit" idea leads him to the false notion that equation 1 means that the voltage increases indefinitely, rather than only to $\omega t = 2\pi$. Third, his statement that the voltage induced consists only of the motional term "as may easily be verified by experiment" is untrue. Cohn never made or observed any such experiment. Had he actually performed the experiment (and done it right) he would have readily found:

1. Heat in the disk due to the induced eddy currents, and these eddy currents exist also if the disk is *not* rotating.

2. The remaining (or motional component cos $\omega' t$) of the voltage will not be measured in full by the meter, because the eddy currents will reduce the effective flux density.

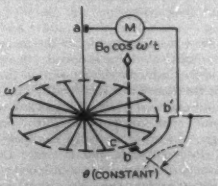


Figure 2. "Substitution of circuit" as each spoke in succession passes the brush

This is a case in which certain effects (the induced eddy currents) mask the thing we want to measure (the *total* induced voltage). For that reason the single-spoke wheel with interrupted rim, or the multiple-spoke wheel of Figure 2, must be used to find experimentally what we are after. If it be objected that a single spoke is hardly a disk, we have only to observe that the same analysis holds for several spokes, and a solid disk may be looked on as an infinite number of spokes infinitely close together.

May I point out that this example goes further than its own interest—a better example could hardly have been chosen for forcing recognition of the idea of a "substitution of circuit," first proposed in my paper "Flux Linkages and Electromagnetic Induction," AIEE *Transactions*, volume 48, 1929, page 327. In Cohn's article, "Electromagnetic Induction" (*EE, May '49, pp 441–7*), he rejected the idea entirely.

It is regrettable that Cohn would imply that his erroneous conclusions were verified by experiment. It is hardly fair to drag red herrings across the path of scientific investigations.

L. V. BEWLEY (F '47)
(Lehigh University, Bethlehem, Pa.)

Power Electronics

To the Editor:

In the August 1949 issue of *Electrical Engineering*, C. H. Willis presents several examples in an article, "Power Electronics as an Educational Medium (*EE, Aug '49, pp 647–9*). These are apparently considered ideal for "stimulating student interest."

The problem of metering a load consisting of a "pure" resistance in series with a load as illustrated in his Figure 3 is one which is more likely to confuse the student rather than interest or instruct him.

Any student sufficiently advanced to tackle the problem would normally be aware of:

1. The fact that problems of this type may call for application of the notion, if not the detail, of a Fourier series.

2. The pitfalls set by meters which may read mean, peak, or rms.

3. The ambiguity of the term "in phase" when applied to dissimilar functions having the same period.

Having solved the problem to his own satisfaction, the student may not unreasonably wonder just what his instructor has been attempting to illustrate. The problem has "Danger" signs hung all over it: "Danger—Alternating Voltages and Direct Currents at Work"; "Danger—Unknown Meter Movements at Work; "Danger—Instructor Prattling About Phase Relationships Between Dissimilar Periodic Functions"; "Danger—Nonlinear Resistance."

Also, someone has connected the voltmeter on the wrong side of the wattmeter.

A. G. BENEDICT
(Brisbane Water County Council, Gosford, New South Wales, Australia)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

PHYSICS, PRINCIPLES AND APPLICATIONS. By H. Margenau, W. W. Watson, and C. G. Montgomery. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 760 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $5. Covering both classical and modern physics, this textbook is designed for undergraduates who require a thorough and accurate introduction to engineering and the physical sciences. All recent advances in physics, understandable on an elementary level, have been included mainly as examples of fundamental principles. The topics introduced on this basis range from the heat pump to nuclear physics.

PRINCIPLES OF ELECTRICITY AND ELECTROMAGNETISM. (International Series in Pure and Applied Physics). By G. P. Harnwell. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 670 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6. Both experimental and theoretical electricity are covered, with more emphasis on the experimental aspect. The changes in the second edition are based on the advances made during the last decade. The accounts of electronics and radiation are expanded in the direction of the higher frequencies, and brief accounts of generators of these frequencies and of resonant cavities and wave guides are now included. More attention is now devoted to the physics of solid conduction, the magnetic properties of atoms and nuclei, and high-energy electromagnetic ion accelerators. New problems have been added.

RADIO WAVE PROPAGATION, Consolidated Summary Technical Report of the Committee on Propagation of the National Defense Research Committee. C. R. Burrows, Chairman; S. S. Attwood, Editor. Academic Press, Inc., New York, N. Y., 1949. 548 pages, illustrations, diagrams, charts, tables, 11 by 8 inches, cloth, $8.80. In this consolidation of three volumes, a record of the wartime activities and developments in the field of propagation of radio waves through the troposphere is given: Volume I gives a critical overall view of the technical developments in the study of tropospheric propagation, and conference reports on standard and nonstandard propagation. Volume II considers the advances in meteorology and various radio wave propagation experiments. In Volume III, propagation of radio waves through the standard atmosphere is dealt with.

SCIENCE AND ENGINEERING OF NUCLEAR POWER, Volume II. By A. O. Allen and others, edited by C. Goodman. Addison-Wesley Press, Kendall Square Building, Cambridge 42, Mass., 1949. 317 pages plus index, illustrations, diagrams, charts, tables, 10¾ by 8 inches, cloth, $7.50. Of value to those interested in the industrial applications of nuclear energy, this volume contains 17 pages on specific aspects of the subject. Source materials, isotope separation, various aspects of pile design, applications to rockets, effects of radiation, health physics, and future developments of nuclear energy are discussed.

TABLES OF BESSEL FUNCTIONS OF FRACTIONAL ORDER, Volume 2, prepared by the Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards. Columbia University Press, New York, N. Y., 1949. 365 pages, tables, 10¾ by 8 inches, cloth, $10. The present volume, devoted to the tabulation of $J_\nu(x)$ for $\nu = 1/4, 1/2, 3/4, 1/4$, is a sequel to the volume containing $J_\nu(x)$ for the same orders. The functional values in both volumes are given either to ten decimal places or to ten significant figures. The tables cover a range of x from 0 to 25. Tables for facilitating interpolation and a list of constants are included.

TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS FORTY THROUGH FIFTY-ONE. (Annals of the Computation Laboratory of Harvard University, Volume XI). By the Staff of the Computation Laboratory. Harvard University Press, Cambridge, Mass., 1948. 620 pages, tables, 10¾ by 7⅞ inches, cloth, $10. Continuing the series of tables computed by the automatic sequence controlled calculator, the present volume extends the coverage of Bessel functions of the first kind. Computational techniques and the calculator itself are described in earlier volumes of the series. As before, the tables are carried to ten decimal places.

TABLES OF THE CONFLUENT HYPERGEOMETRIC FUNCTION $F(\alpha/\gamma, 1/\gamma; z)$ and RELATED FUNCTIONS (National Bureau of Standards, Applied Mathematics Series 3). United States Government Printing Office, Washington, D. C., 1949. 73 pages, diagrams, tables, 10¾ by 8 inches, paper, $0.35. These tables, of importance in connection with the so-called analysis-of-variance tests, are also intended to facilitate the construction of other tables needed for sequential analysis and various other statistical tests. The tables are carried out to six decimal places. The analytical properties of the function are discussed, and a group of interpolation charts are included with explanation.

TABLES OF GENERALIZED SINE- AND COSINE-INTEGRAL FUNCTIONS: Parts I and II (Annals of the Computation Laboratory of Harvard University, Volumes XVIII and XIX). By the Staff of the Computation Laboratory. Harvard University Press, Cambridge, Mass., 1949. Part I, 462 pages; Part 2, 560 pages; charts, tables, 10¾ by 8 inches, cloth, $10 each volume. The introduction to this 2-volume set describes the characteristics, computation, and interpolation of the functions considered. The 6-place tables, expanded from short tabulations prepared for war work, are useful mathematical tools for the investigation of such questions as self- and mutual impedances, radiation resistance, and distribution of current in antennas and antenna arrays of various types.

THEORY OF OSCILLATIONS. By A. A. Andronow and C. E. Chaikin. English edition edited under the direction of S. Lefschetz. Princeton University Press, Princeton, N. J., 1949. 358 pages, diagrams, charts, tables, 9½ by 6 inches, cloth, $6. A condensed version of one published in 1937 in Russian and containing the first extensive treatment of nonlinear oscillations. It begins with a treatment of linear systems, but progresses to various types of nonlinear systems using both mechanical and electrical examples. Special attention is given to self-excited oscillations. There is a bibliography of the most accessible books and papers.

BASIC COURSE IN ELECTRONICS, a Textbook for Midshipmen of the United States Naval Academy. Published by United States Naval Institute, Annapolis, Md., 1948. 394 pages, illustrations, diagrams, charts, tables, 9 by 5¾ inches, cloth, $5. Presents the principles upon which electronic devices and their associated electric circuits are based. Stress is placed upon fundamental theory and important mathematical relationships, circuit design and usage. The first part deals with the circuit-elements and other material of radio communication. The remainder is devoted to new concepts dealing with recent developments in electronics. A knowledge of d-c and a-c circuits and machinery is assumed. Some 50 pages of problems and review of questions are included.

EINFÜHRUNG IN DIE ELEKTROTECHNIK. By E. Dünner. Rascher Verlag, Zürich, Switzerland, 1947. 476 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, cloth, 36 Sw.frs. This introductory text for electrical engineering students presents the principles of electricity and of electric equipment. Transformers, synchronous and asynchronous motors, d-c motors, commutators, converters, and electron tubes are treated. Considers measuring techniques, electrical construction, and materials used in electric equipment. Some 50 books for further reference are listed, grouped according to the chapters to which they relate.

ELECTRIC-MOTOR CONTROL GEAR, STARTING, PROTECTION AND SPEED. By J. L. Watts. Electrical Review, Ltd., distributed by Iliffe and Sons, Ltd., London, England, 1948. 84 pages, illustrations, diagrams, charts, tables, 8¾ by 5¼ inches, fabrikoid, 5s. Of interest to all concerned with the installation, maintenance, and performance of electric motors, this book explains from a practical viewpoint the principles underlying the construction and operation of various types of control gear.

ELEKTRONENSTRAHL - OSZILLOGRAPHEN, BAND I. By P. E. Klein. Weidmannsche Verlagsbuchhandlung, Berlin and Frankfurt, Germany, 1948. 210 pages, illustrations, diagrams, charts, tables, 9¼ by 6½ inches, stiff cardboard, DM 19. Presents a summary of the workings of numerous types of cathode-ray tubes and the connections and operations of necessary auxiliary instruments. A great part of the text is devoted to oscillograph amplifiers. Many tables, diagrams, circuits, and photographs are included as well as references to books, articles, and patents.

ELEMENTS OF ELECTROMAGNETIC WAVES. By L. A. Ware. Pitman Publishing Corporation, New York, N. Y., and London, England, 1949. 203 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. Employing the rationalized MKS units, this text gives electrical engineering students an introduction to the basic ideas of electromagnetic theory. A knowledge of calculus and basic a-c theory is assumed. Vector algebra is introduced as needed. Many illustrative examples and problems are included, and such topics as wave guides and antennas are included as applications of the theory.

ENGINEERING OPTICS. By K. J. Habell and A. Cox. Sir Isaac Pitman and Sons, Ltd., London, England, 1948. 411 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, 35s. A critical survey of the most important optical methods and instruments that are applicable to engineering practice. The properties of ideal optical systems and actual systems are discussed. Light and illumination, microscopes, telescopes, optical projection, and profile microscopes are considered in detail.

ESSENTIAL METALLURGY FOR ENGINEERS. By A. C. Vivian. Third edition. Sir Isaac Pitman and Sons, Ltd., London, England, 1948. 180 pages, illustrations, diagrams, charts, tables, 8¼ by 5⅜ inches, cloth, 12s.6d. Written for engineering students, this book is devoted to the causes and control of the properties of metals and alloys. Amorphous and crystalline structure, solid solutions, and eutectics are considered prior to mechanical properties and metallurgical techniques. Various alloys are dealt with in detail. A glossary of terms is included.

HANDBOOK OF PLASTICS. By H. R. Simonds, A. J. Weith, and M. H. Bigelow. Second edition. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1949. 1,511 pages, illustrations, diagrams, charts, tables, 9½ by 6½ inches, cloth, $25. Beginning with a survey of the industry which lists producers and fabricators, this book covers the plastics field exhaustively from raw materials to finished products. It gives details of the manufacturing methods, machinery and processes for the plastics themselves; also for the many articles into which they are fabricated. It includes plastics of all compositions and all manufacturers, with the specific properties which determine their applications and their choice for any particular purpose, use or method of processing. The thorough revision includes the enlarging of the chapters on chemistry and on analysis, the full coverage of postforming and low-pressure molding, and the addition of sections on laminating, stress and strain, patents and accounting. There is a 57-page list of trade names and trade-marks.

HOCHSTROMKOHLEBOGEN. (TECHNISCHE PHYSIK IN EINZELDARSTELLUNGEN, volume 6, edited by W. Meissner.) By W. Finkelnburg. Springer-Verlag, Berlin, Göttingen, Heidelberg; J. F. Bergmann, Munich, 1948. 221 pages, illustrations, diagrams, charts, tables, 9½ by 6½ inches, paper, 22.50 M. Presents the physics and technology of high-tension carbon arcs. Following a short summary of the properties and mechanisms of low-tension carbon arcs, the general properties and operation of high-tension arcs are discussed. The physical properties, mechanisms, and theory of high-tension arcs are then considered in detail.

INDUSTRIAL ELECTRONICS AND CONTROL. By R. G. Kloeffler. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1949. 478 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $5.50. This book is designed for the student whose major interest is in the electric power, mechanical, or chemical engineering field, rather than for the communications major. Beginning with Bohr's early theory of the atom, the author proceeds to the basic theory of electron tubes, associated circuits, and control component devices. The latter part of the book covers the major applications in the industrial and commercial fields.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Review of Current Research and Directory of Member Institutions, 1949. Describes research projects in engineering subjects now being conducted by the 82 colleges and universities which hold membership in the Engineering College Research Council of the American Society for Engineering Education. The 186-page book is available at $1.75 per copy from F. M. Dawson, College of Engineering, State University of Iowa, Iowa City, Iowa.

Schematic Manual for Surplus Electronic Equipment, PB 98487, Volume I. First of a series of publications providing prospective purchasers of Government surplus electronic equipment with basic circuit diagrams, and characteristics of the more common types of apparatus available. Selling for $1, the 44-page manual is obtainable from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C., check or money order payable to the Treasurer of the United States.

Wings for the Transit. Explains how topographic maps are produced from precision aerial photographs. Copies of the booklet may be obtained from Lockwood, Kessler, and Bartlett, Inc., 32 Court Street, Brooklyn 2, N. Y.

Three NEMA Publications. "Definitions for Marine-Propulsion Steam Turbine Electric Equipment (A-C)," Publication Number MP3-1949. Designed to aid in developing standards; 12 pages, sells for $1.25. "Standards for Rubber Insulated Building Wire and Cable, 0-5,000 Volts," Publication number RV2-1949. Dimensions, insulation, covering, and testing of types *R, RH, RW,* and *RU* wire and cable are given; 40 pages, priced at $1.25. "Standards for Thermoplastic Insulated Building Wire and Cable, 0–600 Volts," Publication Number RV1-1949. Gives dimensions, insulation, physical and aging requirements, and testing and electrical requirements of types *T* and *TW* wire and cable; 24 pages, sells for 90 cents. All three publications are available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

The Electron Microscope and Its Application to Materials Problems, PB 97957. Prepared to assist in the training of Air Force technicians, the manual gives basic theory, operation, and applications of the electron microscope. 48 pages. Priced at $1.25. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C., check or money order payable to the Treasurer of the United States.

Handbook on Fabricated Natural Mica. Describes the properties and processing of two common types of mica, Muscovite and Phlogopite. 15 pages. Available from the Mica Fabricators Association, 420 Lexington Avenue, New York 17, N. Y.

An Introduction to the Dynamics of Compressible Fluids, PB 97906. Designed to equip beginners in the study of hydrodynamics for further work in gas dynamics research. 160 pages. Priced at $20 in photostat or $6 in microfilm, the book is available from the Library of Congress, Photoduplication Service, Publication Board Project, Washington 25, D. C., check or money order payable to the Librarian of Congress.

Engineering Handbook of the National Association of Broadcasters, Fourth Edition. Contains Federal Communications Commission rules and regulations and technical information on radio, television, and audio engineering. Running to nearly 700 pages, it is priced at $17.50. Available from the National Association of Broadcasters, 1771 N Street, N. W., Washingon 6, D. C.

United States Atomic Energy Commission and Contracting and Purchasing Offices and Types of Commodities Purchased. Tells what products are bought by the AEC and how business men can go about selling their goods to the Commission and its contractors. Priced at ten cents, it is available from the United States Government Printing Office, Washington 25, D. C.

Supplement to "Steam-Electric Plant Construction Cost and Annual Production Expenses." The supplement gives 1948 costs for 199 of the 200 plants covered in the original study and also presents data on 19 new generating plants. Copies of the supplement (order number FPC S-74), are available at 50 cents. The original volume (FPC S-72), covering data for the 10-year period, 1938–47, is priced at $3. Send remittances to the Federal Power Commission, Washington 25, D. C.

Hot-Tinning, by W. E. Hoare. Provides complete working instructions for the production of hot-tinned coatings on fabricated articles and components. 112 pages. Free on request from the Tin Research Institute, Inc., 492 West Sixth Avenue, Columbus 1, Ohio.

NBS Publications. "Bibliography of Books and Published Reports on Gas Turbines, Jet Propulsion, and Rocket Power Plants," National Bureau of Standards Circular 482; 49 pages, 20 cents. "Fundamental Techniques in the Frequency Adjustment of Quartz Crystals," NBS Circular 480, by L. T. Sogn and C. Barclay. Gives methods for changing frequency of high-frequency thickness-shear crystals; 9 pages, 10 cents. "Testing of Hydrometers," by E. L. Peffer and M. G. Blair, NBS Circular 477. Outlines desirable features of hydrometers that will improve their usefulness and facilitate their testing on a uniform basis; 9 pages, 10 cents. All three publications are available from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

Atomic Energy and the Life Sciences. Outlines Atomic Energy Commission program in all phases of medicine and biology. The 203-page book is available at 45 cents from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

The Most Desirable Personal Characteristics. A survey of the opinions of executives and student engineers as to the personality traits desirable in engineering personnel. Priced at 25 cents, the 25-page booklet may be obtained from the Engineers' Council for Professional Development, 33 West 39th Street, New York 18, N. Y.

The V. I. Story, Varnished Insulations in Electrical Engineering, by D. O. Woodbury. Describes types and uses of varnished insulations. Priced at $1, the 88-page booklet is available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

RCA Technical Papers (1948), Index, Volume II(c). Bibliography of papers on electronics and related fields presented in 1948, the authors or coauthors of which were associated with the Radio Corporation of America. Available from the *RCA Review,* Radio Corporation of America, RCA Laboratories Division, Princeton, N. J.

Electric Power Supply, by T. H. Carr. Consists of a series of articles originally published in the British *Beama Journal* under the title of "Reliability of Supply in Electric Power Stations and Sub-stations." 60 pages. Available for the equivalent of two shillings from The Cyril Williams Publicity Limited, 69 Swan Arcade, Bradford, Yorkshire, England.

Prospecting for Uranium. Tells where to look for the metal, and how to test for it, gives selling procedures, and deals with legal questions. 123 pages. Obtainable for 30 cents from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

***Transactions of the Danish Academy of Technical Sciences, 1948, Number 3.** Describes investigations into stray currents in underground structures and experiments with cathodic protection of the heating pipe system of Copenhagen. 111 pages. For further information, write Johs. E. Børresen, The Copenhagen Lighting Department, Municipal Gas and Electricity Works, Copenhagen, Denmark.

Some Performance Characteristics of Electrical Brushes, by E. E. Jones and M. S. Coover. Iowa Engineering Experiment Station Bulletin 162. Discusses tests on metal-graphite brushes made under conditions of low humidity and describes means for producing such conditions. 58 pages. For further information, address The Iowa Engineering Experiment Station, Iowa State College, Ames, Iowa.

Commutator and Slip Ring Maintenance. A handbook of methods and procedures which have been proved over many years in hundreds of operations. The 39-page booklet is available from Ideal Industries, Inc., Sycamore, Ill.

The O. H. Hutchings Station of The Dayton Power and Light Company. Describes mechanical and electrical features of the station. Free on request from K. C. Long, President, The Dayton Power and Light Company, Dayton 1, Ohio.

Why we quit making rubber-covered cannon balls

We have made—and quit making—a lot of things during our nearly 100 years in business. Because of our "know-how" in making insulation of unusual durability, we were asked to develop rubber-covered cannon balls to reduce wear-and-tear on cannon, during the war between the states.

It was an interesting job—but the solution to cannon wear was tougher cannon rather than softer cannon balls.

We have retained our "know-how" in making insulation, however—and since those early days, we have made a lot of new developments. We developed the first insulated wire for Samuel Morse's telegraph. We pioneered in submarine cable well before the turn of the century. We even had to develop extruding machinery to apply insulation to wire and cable.

In recent years, Kerite has led in the development of self-supporting aerial cable, high-voltage x-ray cable which no one else could build satisfactorily, and in many other fields.

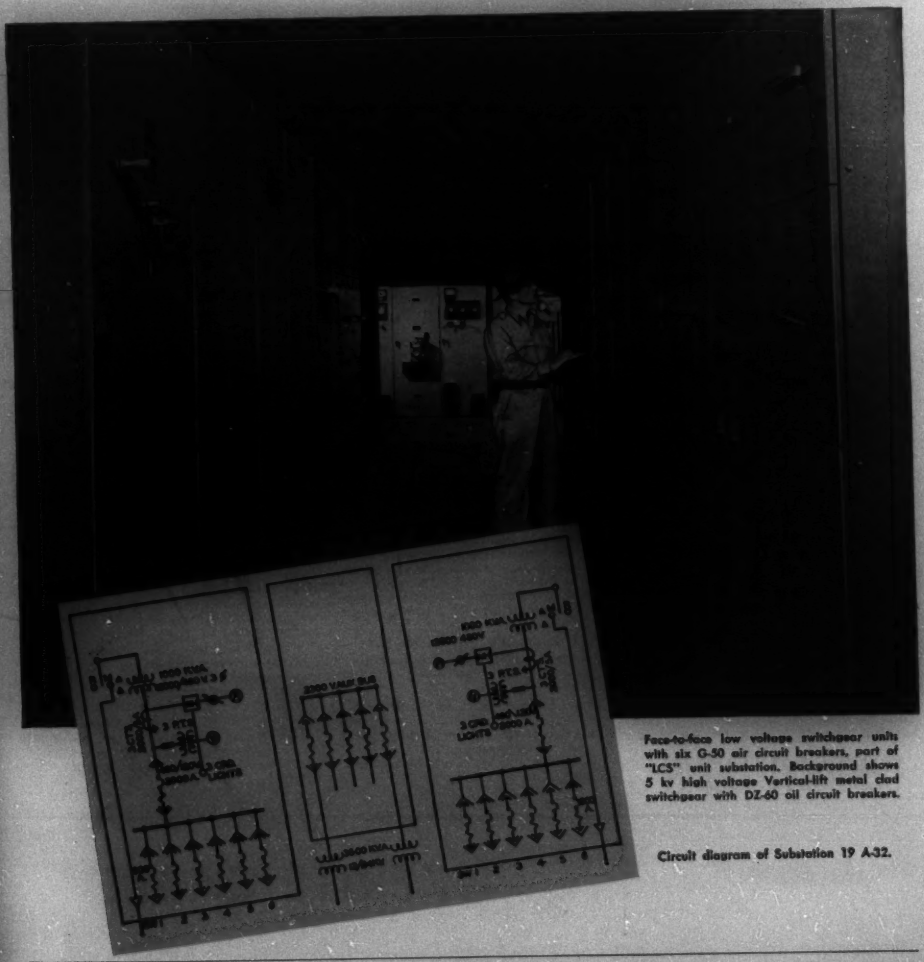
Kerite insulation—made only by Kerite—provides unusually long life and low cost per year. Why not ask a Kerite engineer to help put it to work for you? *The Kerite Company, 30 Church Street, New York 7, N. Y.*

Offices also at: 122 So. Michigan Avenue, Chicago; 582 Market Street, San Francisco; 714 W. Olympic Blvd., Los Angeles.

Kerite Insulation—Your Cable's Best Life Insurance

KERITE CABLE

Here's the Inside Power Protection at



Face-to-face low voltage switchgear units with six G-50 air circuit breakers, part of "LCS" unit substation. Background shows 5 kv high voltage Vertical-lift metal clad switchgear with DZ-60 oil circuit breakers.

Circuit diagram of Substation 19 A-32.

Story on

CORN PRODUCTS REFINING CO.

***All* power at Corn Products Refining Co.'s Argo, Illinois, plant is controlled by Allis-Chalmers High and Low Voltage switchgear — insuring constant power for production of Karo Syrup, Mazola Salad Oil, Kre-Mel dessert, Argo and Linit Starches.**

IF YOU COULD GO behind the scenes at Corn Products, you would see why these household products owe their pure quality to *controlled* production. Many complex operations involve grinding mills, filters, converters and oil expellers to transform corn into starches, syrups, sugars, dextrines and oil . . . all of which must be supplied unfailing electric power!

Protection for Equipment.

Engineers at Corn Products, like many others, have turned to Allis-Chalmers switchgear to protect this costly equipment. There are 15 groups of low voltage switchgear housing 90 G-50 600-volt air circuit breakers in addition to primary high voltage Vertical-lift switchgear with 600 and 1200 ampere oil circuit breakers.

In Argo's building 53, starch is converted to syrup. Boiler house and substation on right.

This standard Allis-Chalmers switchgear is engineered to provide complete protection to operating personnel and equipment.

Standardized.

With today's increasing demand for electric power, industries need better power protection. For a *sure* answer look into the advantages of Allis-Chalmers standardized switchgear.

Easy to install. All-steel enclosed. Safety-engineered. Breakers mechanically trip-free. These features add up to give you economical power protection. Call your nearby Allis-Chalmers district office or write direct.

Low voltage switchgear with G-50 air circuit breakers and 1000 kva dry type transformer.

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

ALLIS-CHALMERS

First in the U. S. with Metal-Clad Switchgear

A-2805

Silicone News

DC SILICONES

Here's How DC Silicone Insulation Reduces Motor Failure

Photo courtesy Virginia-Carolina Chemical Corp.

THIS 300-H.P. silicone insulated motor was back in service three hours after being flooded with water, mud and waste.

• Engineers of Virginia-Carolina Chemical Corporation agree that DC Silicone Insulation is the best solution to motor failure caused by excessive moisture. They proved this in two identical 300-h.p. motors, one wound with Silicone (Class H) and the other with Class B insulating materials.

Located side by side and exposed to the same operating conditions, these motors are used to pump waste materials at the Phosphate Mine in Homeland, Florida. After the main line broke last year and flooded both motors with water, mud and waste, the Class B motor had to be reworked and rebaked. The motor wound with Class H insulation was simply cleaned with an air hose and the bearings were flushed out . . . *Three hours later, the SILICONE INSULATED motor was back in service and operating perfectly.*

That confirms again the fact established by 4 years of motor testing: Class H insulation made with Dow Corning Silicones has at least 10 times the life and 10 times the wet insulation resistance of the best insulating materials previously available. For more information on how silicone insulated equipment can save you time and money, phone our nearest branch office or write for booklet M-12.

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FIRST in Silicones
Dow Corning

INDUSTRIAL NOTES ....

Minnesota Mining and Manufacturing Advances Five in Top-Level Management. William L. McKnight, President of the Minnesota Mining and Manufacturing Company since 1929, has been elected to the newly created post of Chairman of the Board of the company; successor to the presidency is Richard P. Carlton, former executive Vice-President. Archibald G. Bush, former Executive Vice-President, becomes Chairman of the Executive Committee; and George H. Halpin and Herbert P. Buetow have both been elected as Executive Vice-Presidents.

Rome Cable Acquires Andersen-Carlson Manufacturing Company. The Rome Cable Corporation, Rome, N. Y., has announced the acquisition of the Andersen-Carlson Manufacturing Company, Torrance, Calif., manufacturers of electric metallic tubing for the construction industry since 1946. The California plant will continue operation under the direction of Messrs. Arthur A. Andersen, President, and Gilbert Woodill, Executive Secretary. No change in personnel is contemplated.

IGE Promotion. V. C. Jesperson has been named Sales Manager in the International General Electric Company's Electronics and Merchandising Division. Mr. Jesperson's office will be in New York City.

General Electric Advances Roberts. C. G. Roberts has been appointed Product Manager for broadcast and television equipment for the General Electric Company's Transmitter Division at Syracuse, N. Y.

Westinghouse News. Edward G. F. Arnott has been named acting Research Director of the Westinghouse Lamp Division at Bloomfield, N. J. Mr. Arnott, a specialist in the study of gas discharges for fluorescent lamps and electronic tubes, succeeds Dr. Charles M. Slack, who was recently appointed Technical Director of the Westinghouse Atomic Power Division in Pittsburgh, Pa. The company has also appointed Ray H. Timmons as Manufacturing Manager of industrial products; C. M. Clark to Mr. Timmons' former post, Superintendent of Manufacturing for the Transportation and Generator Division; and R. P. Wagner, Manager of the industrial products Advertising and Sales Promotion Department.

Kaiser Engineers, Inc., Changes Name. The corporate name of Kaiser Engineers, Inc., has been changed to Kaiser Industries, Inc. The engineering and construction division will continue to do business as Kaiser Engineers, a Division of Kaiser Industries, Inc. The name change in no way affects the operations, functions, or personnel of Kaiser Engineers, who are currently completing the design and construction of additional facilities at the Kaiser Steel mill at Fontana, Calif., estimated to cost approximately $35,000,000. Other projects recently finished or nearing completion under their direction include the installation of wire and cable-making equipment costing $4,500,000 at the Permanente Metals aluminum mill, Newark, Ohio, and a new $2,000,000 porcelain enameling plant for Kaiser Metal Products, Inc., at Bristol, Pa.

Roger S. Warner Joins Arthur D. Little, Inc. Following his resignation as Director of Engineering for the Atomic Energy Commission, Roger S. Warner has announced that he has joined the staff of Arthur D. Little, Inc., Cambridge, Mass., research and engineering organization.

William Brand and Company Appointment. Robert M. Robinson has been named Sales Manager of William Brand and Company, manufacturers and distributors of the Turbo line of electrical insulating materials.

Minneaplis-Honeywell Expands Facilities. A one-story factory building containing 102,000 square feet has been purchased by the Minneapolis-Honeywell Regulator Company to accommodate expansion made necessary by stepped-up activity of the company's Special Products Division. This division manufactures the aeronautical control devices made by Honeywell for commercial and military aircraft. More than 300 employees are being transferred to the new location at 1433 Stinson Boulevard, Minneapolis, Minn.

Elliott Company Acquires Crocker-Wheeler. The Elliott Company, producers of steam, power, and electric equipment for process plants, has acquired the business and assets of the Crocker-Wheeler Division of the Joshua Hendy Corporation. The Division will continue to operate under its previous management with Charles A. Butcher as General Manager. Mr. Butcher has also been elected a Vice-President of the Elliott Company.

Transformer Division of Larkin Moves. The Larkin Transformer Division of the Larkin Lectro Products Corporation has relocated their entire plant and office facilities to larger quarters in Pine Bluff, Ark. Their production of liquid-immersed and dry-type power and distribution transformers will be expanded to include sizes up to 10,000-kva and 69-kv class.

Air Reduction Management Changes. H. R. Salisbury has been made President of the Air Reduction Sales Company, and H. F. Henriques, J. J. Lincoln, Jr., S. B. Stouffer, and N. L. Wisser were appointed Vice-Presidents.

Dr. James G. Buck Joins Sylvania Research Staff. Dr. James G. Buck has been named Head of the cathode chemistry group at the Product Development Laboratories, Sylvania Electric Products, Inc.

(*Continued on page 22A*)

PACIFIC ELECTRIC

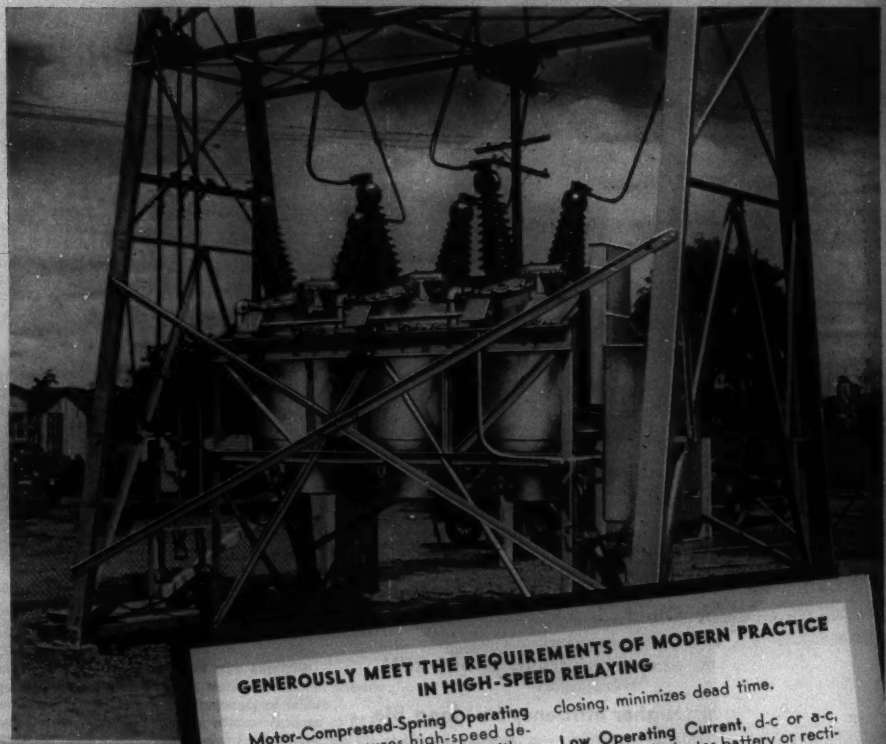
BREAKERS

69 kv, Type JE-42

Extra-Fast

Fault Interruption and Reclosures

by Motor-Compressed-Spring Stored-Energy Operating Mechanism



Type JE-42E
69 kv 600 amps
1,000,000 interrupting kva

Type JE-42F
69 kv 1200 amps
1,500,000 interrupting kva

Fully Conform to
AIEE and NEMA
Adopted Standards

GENEROUSLY MEET THE REQUIREMENTS OF MODERN PRACTICE IN HIGH-SPEED RELAYING

Motor-Compressed-Spring Operating Mechanism assures high-speed dependable opening and closing, either automatic or manual; ideal for synchronizing.

High-Velocity Gas Blast, directed into the arc stream, rapidly extinguishes the arc within Pacific Electric Expulsion Chambers.

High-Speed Tripping, for opening and closing, minimizes dead time.

Low Operating Current, d-c or a-c, reduces or eliminates battery or rectifier expense.

Easy to Inspect and Maintain—Low upkeep even when fault interruptions are abnormally frequent.

Shipped Assembled—Fully tested and adjusted at the factory.

Get All Facts . . .

Call

PACIFIC ELECTRIC MFG. CORPORATION

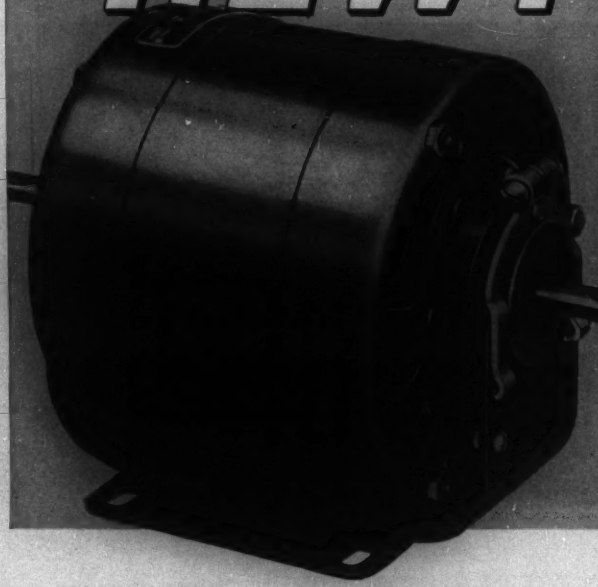
NORTHERN INDIANA EXPANSION COMPANY, SOUTH CHICAGO AVE. & P.O. BOX 418, GARY, INDIANA

NEW!

FASCO

6-POLE
SHADED POLE
MOTORS

1/30 THRU 1/8 HP
1000 RPM



★ Quiet . . . uniform performance at ALL speeds

★ Speed reductions to 500 RPM

★ Higher efficiency . . . long life

★ Mounts to meet every need . . . interchangeable with other motors

"YOUR COMPARISON TEST . . . WILL PROVE FASCO BEST"

FASCO
INDUSTRIES, INC.

WRITE today for full performance data, dimensions, and applications to Fasco Industries, Inc., 150 Augusta Street, Rochester 2, New York.

These coils are designed for continuous operation at

Where standard Class B coils fail with excessive frequency because of high heat, National's special Silicone Mica-Glas coils will reduce the frequency of failure tremendously. They will operate without damage at 356° F., and up to 450° F. under certain conditions. For instance, the life of Class B windings of a motor averaged just 50 days over a four-year period; the same motor in the same work, equipped with National Silicone Mica-Glas windings, has operated for four years without a single failure caused by heat. We can supply such windings for any motor or generator, of foreign or domestic manufacture; they can be installed in our shop or yours, by us or you. If heat-failures cost you money, get in touch with us NOW.

NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

Johns-Manville Announces Two New

Smooth layers of Quinterra Type 6 Electrical Insulation (Twin-ply), used in winding a Marcus dry-type transformer

Quinterra

TYPE 6 (TWIN-PLY)

A new cost-reducing, high-temperature insulation that prolongs transformer life many times through its resistance to pyrolysis

Here is a radically new asbestos-base, continuous-sheet, paper-like electrical insulation that offers many economies. It is primarily intended for interlayer and wrapper insulation in windings and coils used in Class A and B transformers (internal hot-spot temperatures 130C, or higher if special varnishes are employed).

Quinterra Type 6 is plied at the factory by welding two layers of Quinterra and calendering them into a dense, strong and smooth-surfaced insulation having good tensile and bursting strengths. For economical application with a minimum of waste, Quinterra Type 6 is furnished in continuous rolls cut to exact widths.

Excellent handling properties

Uniformity of physical and handling properties enables assemblers to achieve production rates such as are attained with the best types of interlayer and wrapper insulations. Further economies result from the large square-foot-per-dollar coverage.

Excellent constructional advantages

The plied construction of Quinterra Type 6 offers two distinct constructional advantages: (1) It provides better dielectric protection than a single layer. (2) Under stress, the weaving strains within coil structures are less likely to damage a plied insulation than a single-layer insulation.

Excellent dielectric-thermal characteristics

The base sheets of all Quinterra products are made 100% inorganic, but, for mechanical reasons only, are saturated with an organic resin. At room temperature (ASTM conditions) Quinterra Type 6 averages in excess of 350 VPM. After prolonged exposure at 175C, long after the thermoplastic saturant is driven off, it still maintains its original dielectric strength and requires only the re-establishment of its varnish protection to provide a further useful life cycle.

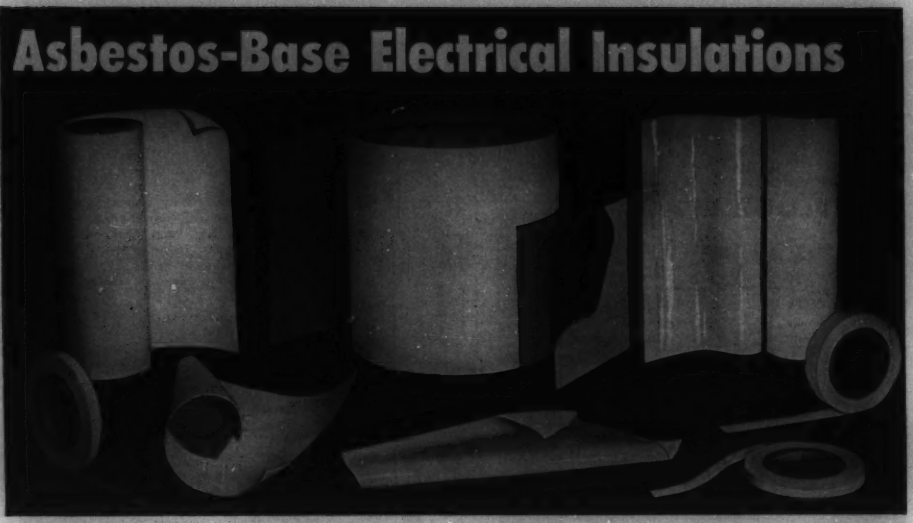
We will be glad to provide you with samples and further information about Quinterra Type 6 Electrical Insulation. Write Johns-Manville, Box 290, New York 16, N. Y.

Weights and thicknesses of Quinterra Type 6

Thickness ±10%	Weight Per 100 sq ft ±15%	Approx Coverage sq ft lb
.0045"	2.5	40
.006"	3.3	33
.007"	3.8	26
.008"	4.5	22
.009"	4.8	20
.010"	5.5	18
.012"	6.2	16
.015"	7.2	14

Johns-Manville

Asbestos-Base Electrical Insulations



A variety of types of electrical insulations as produced by combining glass, mica, and organic papers and films with Quinorgo #3000 or #4000.

Quinorgo

#3000 AND #4000

New, economical, high-temperature insulations with a previously unattainable combination of dielectric and mechanical properties

Quinorgo #3000 and Quinorgo #4000 are two new insulations developed by Johns-Manville. Each can be used alone or in combination with other dielectrics. In the latter use they can be either treated or coated with insulating varnishes, or combined with organic or inorganic electrical insulating sheets or films.

Quinorgo insulations contain 80% or more of specially processed asbestos fiber, the remainder being selected organic fibers and binders. The two types differ in that the organic portion of Quinorgo #4000 contains a small amount (3% or less) of resin not present in Quinorgo #3000. The resin slightly reduces absorption and penetration.

These highly improved forms of asbestos electrical insulations have extreme uniformity of texture and caliper (from .005" to .015"). They are furnished in continuous rolls, in tapes of exact widths and in sheets cut to size.

Excellent for compactness — Quinorgo #3000 and #4000 have important advantages where asbestos papers previously could not be used because they were too thick, their dielectric too low, or strength inadequate.

Excellent for "composites" — Quinorgo #4000, because of its heat resistance, closed nonwoven structure, uniform thickness and special penetration characteristics, is ideal for use in composite insulations.

For example, it may be coated on one surface with shellac or varnish to permit bonding or cementing to it such mechanically or dielectrically stronger materials as inorganic woven cloths and mica or organic cellulose films or sheets. The opposite surface remains ready for absorption of treating varnishes used in the further processing of equipment after the composite insulation has been applied.

Excellent for economies—Quinorgo #3000 and #4000 may be economically substituted for quality grade organic or inorganic layer insulation. When varnish-protected in apparatus, they will perform indefinitely because of their high asbestos content. (Hot-spot temperatures to 130C).

We will be glad to provide you with samples and further information about Quinorgo insulations. Write Johns-Manville, Box 290, New York 16, N. Y.

General average properties of Quinorgo #3000 and #4000

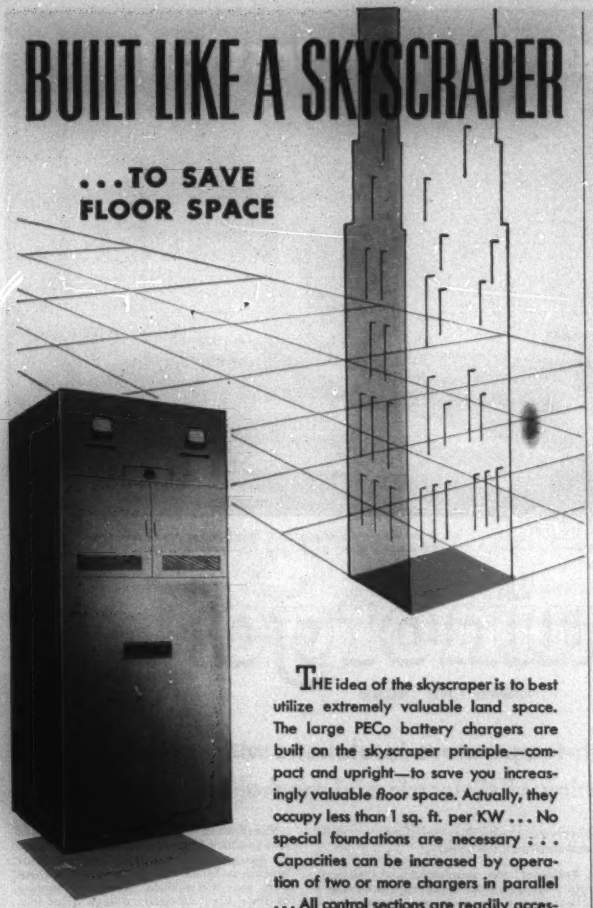
Thickness	Lbs Per 100 sq ft		1" wide Longitudo T.S. lbs		Dielec Min VPM
	3000	4000	3000	4000	3000-4000
.005"	1.5	1.7	14	15	300
.007"	2.2	2.5	18	19	300
.010"	3.3	4.0	20	21	250
.015"	4.7	5.7	26	28	200

Electrical Insulations

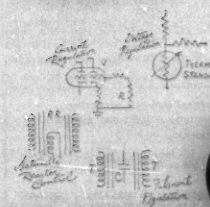
JOHNS-MANVILLE JM PRODUCTS

BUILT LIKE A SKYSCRAPER

. . . TO SAVE FLOOR SPACE



THE idea of the skyscraper is to best utilize extremely valuable land space. The large PECo battery chargers are built on the skyscraper principle—compact and upright—to save you increasingly valuable *floor* space. Actually, they occupy less than 1 sq. ft. per KW . . . No special foundations are necessary . . . Capacities can be increased by operation of two or more chargers in parallel . . . All control sections are readily accessible. Rectifier assemblies are on removable trays to facilitate inspection or service . . . Fully automatic; electronically or magnetically controlled and regulated; accurate floating voltage control within ±1% . . . Complete range of sizes up to 10 KW . . . Write for all the facts.



POWER EQUIPMENT *Company*

55 ANTOINETTE STREET / DETROIT 2, MICHIGAN

(*Continued from page 16A*)

Dr. Buck was formerly an assistant professor of physics at the University of Notre Dame.

Radio Inventions, Inc., Changes Name. John V. L. Hogan, President of Radio Inventions, Inc., has moved his office from 730 Fifth Avenue, New York City, to the laboratory offices at 155 Perry Street, New York, 14, N. Y., and in order to identify all the activities of the organization as closely as possible with him, the name of the corporation has been changed to Hogan Laboratories, Inc. As this is a change in name only, all personnel and corporate organization remain as before.

NEW PRODUCTS . .

Leeds and Northrup Recorder. A new Speedomax recorder now automatically plots the relationship between two variables, showing one as a function of the other. The variables to be plotted are converted to d-c signals, and connected to the instrument, one to the horizontal axis and the other to the vertical axis, resulting in a permanent record, plotted in a few minutes. The new instrument has two circuits, instead of the usual one; pen travel (X axis) is controlled by the Speedomax G electronic circuit; a similar circuit controls the chart paper drive (Y axis) and makes it reversible. Thus, the new recorder makes it possible automatically to draw curves such as a hysteresis loop, temperature versus temperature difference, stress versus strain, or other 2-variable curves. Further information is available by writing to the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

Six-Pole Shaded-Pole Fractional-Horsepower Motor. Fasco Industries, Inc., manufacturers of shaded-pole fractional horsepower motors, have announced a new 6-pole model. Power ratings of the new motor range from 1/8 horsepower to 1/30 horsepower at speeds from 1,000 rpm when operated at rated voltage. Further speed reductions are possible down to 500 rpm by the use of choke control coils. Designs are available for horizontal or vertical operation, and are applicable for use in fans, ventilators, and other types of air movers. Additional information may be had by writing to the company at Rochester, N. Y.

Rotary Actuators. Lear, Inc., 110 Ionia Avenue, N.W., Grand Rapids 2, Mich., has designed a new series of rotary actuators, automatically controlled electromechanical power converters designed to drive mechanisms requiring high torques for a few degrees of rotation or several revolutions. Basic features of the new instruments are split-field reversible, explosion-proof d-c motor; electromagnetic brake; planetary gear assembly; and circuit switch assembly. Weight reductions

(*Continued on page 38A*)

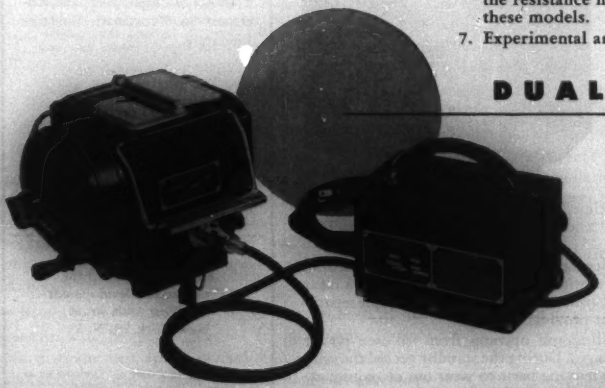
NEW "MEGGER"* Rectifier-Operated Insulation Testers

RECTIFIER-OPERATED

. . . in which a transformer and rectifier replaces the usual hand-cranked generator. It operates simply by plugging into 115 v. 60 cycles.

Typical Applications include:

1. Production testing of all types of electrical equipment and components.
2. Testing multi-conductor communication cables, as in telephone plants.
3. Testing multi-conductor control circuits in power plants.
4. Acceptance tests, such as from load centers, in lighting and power installations.
5. Testing multi-conductor control and power circuits at central locations in railway signal installations.
6. Testing generators, cables and other equipment by the time-resistance method, where the dielectric absorption or leakage current of the insulation under test is high enough to bring the resistance measurement within the range of these models.
7. Experimental and laboratory use.



DUAL-OPERATED

. . . a combination of the popular, constant-voltage, hand-cranked set, and a separate rectifier. It can be operated either by hand or by the rectifier connected to 115 v. 60 cycles. This Dual-Operated instrument has the same applications as the instrument above, *plus* the fact that the basic, hand-cranked instrument is available for test problems normally encountered in the field.

• *For full particulars please write for new illustrated Bulletin 21-46-EE.*

*REG. U. S. PAT. OFF.

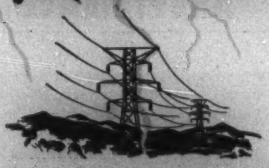
JAMES G. BIDDLE CO.

Electrical & Scientific Instruments

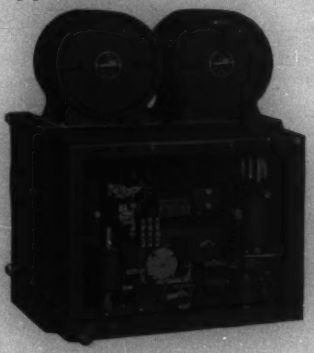
1316 ARCH STREET, PHILADELPHIA 7, PA.

"Megger" INSULATION TESTERS • GROUND TESTERS • OHMMETERS

Lightning-Fast Records..



..with this G-E Automatic Oscillograph type PM-13



In one quarter cycle this automatic instrument goes into action. It provides you with detailed, graphic records of how your power system behaves under all fault conditions. This information can help you—

1. Reduce loss of service. Faults are more quickly located for repair
2. Save money on special patrol expense
3. Detect minor faults before they cause major damage
4. Determine causes of system instability
5. Supervise relay and breaker operation.

THE PM-13 IS FULLY AUTOMATIC. No operator is needed. It starts (in 1/240 second), records entire disturbance, and stops after fault has been cleared. Operation can be initiated by any device that will break a circuit, so it is suitable for use at an unattended station. It will make 100 oscillograms without attention.

CLEAR, WELL-SPACED RECORD. A special arrangement prevents crowding at the start, and the lamp burns more brightly at that time to assure a clear starting record. The trace paper is 4¼ inches wide. This permits ample separation of traces yet avoids the high cost of wider paper.

DEPENDABLE OPERATION. This oscillograph operates from its own power source (automatically kept at full voltage). During the standby period the only part energized is the light source—no moving parts to wear out or require attention. No special skills are required to care for it.

MORE ADVANTAGES—Built-in alarm contacts, adjustable recording time (two to twenty seconds), and time-stamp identification (date, hour, and minute of record) are just some of the other reasons why you'll appreciate every PM-13 in your system. You can order now from your nearest G-E representative. Or, if you want more information, write for Bulletin GEC-396. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

ENGINEERING as a CAREER

A MESSAGE TO YOUNG MEN, TEACHERS AND PARENTS

This pamphlet has been prepared as an educational guide, in order to give something of an introductory insight into the profession of engineering. It is dedicated to the coming generation of engineers and to the constructive contributions which they will make to the life and culture of mankind. Contents of the booklet have been divided into three main parts: The Scope of Engineering; Principal Branches of Engineering; and References to Vocational Guidance Literature.

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USING THE COUPON BELOW

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NAME .....

ADDRESS .....

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Operating board of a 4-unit station. Normally all 4 are on base load during day; two units usually regulate frequency as the evening peaks develop. As peaks fall, units go to reduced base load and another station takes over regulation. In morning, regulation comes back in approximate reverse. Station often handles emergency regulation during day; system operator, 100 miles away, uses its individual units as he wishes to increase system efficiency.

MULTI-UNIT LOAD-FREQUENCY CONTROL IS CUTTING KW COST

Economy-minded managers in several power companies are now digging into the newer efficiency angles of load-frequency regulation. In routine system regulation, which maintains minute-by-minute balance between generation and consumer load, these engineers suspect there lie untapped opportunities for further savings.

Basically, of course, the regulating problem is to allocate load-frequency control for maximum *system* (as distinguished from *station*) efficiency. And the allocation naturally varies with the load; at one load level Units A and B may be best; at another level it may be Units E and G, and L, in stations miles apart.

These flexible conditions mean that an electric company should be able to pick and choose, not only among stations, but among the generating units in the stations. Operators should be free to put the load-frequency regulation wherever the existing load, considered in respect to the unit efficiencies, can be carried at the best system efficiency.

Planned Regulation Costs Less Than Haphazard

To attain this efficiency, it's usually advisable to employ automatic regulation. If a company already uses L&N equipment for other load-frequency problems, it probably will need only a little more to equip each Unit with its own controller. Then complex regulating schedules do not matter. The operators can set a few dials and switches, and assure highest feasible efficiency.

For further information, ask for a copy of Technical Publication N-56-161(1). Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl Ad ND66-481(1)

Preformed? YES!
Bethanized? YES!

FORM-SET STRAND HAS BOTH ADVANTAGES

In recent months a good many users of strand have decided that Bethlehem's Form-Set will do a better job for them. Maybe you've reached that decision yourself. You've investigated Form-Set and learned that its preformed construction makes it easier to handle . . . easier to insert in fittings . . . because, when cut, Form-Set doesn't unravel or "bush out" at the ends. But possibly you haven't thought to ask whether it's available with a bethanized coating.

The answer is yes! In fact, bethanizing is standard on all types, grades, and sizes of Bethlehem strand, both preformed and non-preformed.

The bethanized coating is a smooth, uniform jacket of highly-pure zinc—a coating so ductile that it will bend without cracking. The coating is available in three different weights—A, B, and C—making it possible to protect against atmospheric corrosion in any given area.

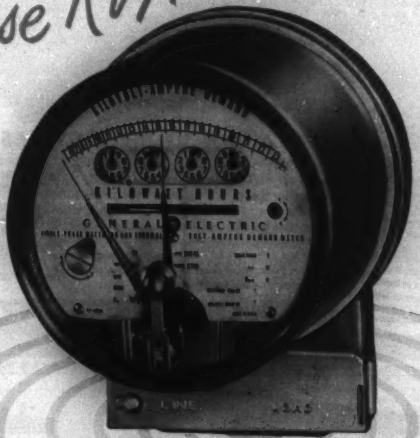
Form-Set strand, with the guardian bethanized "armor," well warrants your investigation. We know that it will not disappoint you. However, if there are still some angles you'd like to discuss, a Bethlehem man will be glad to give you further information.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

GENERAL ELECTRIC ANNOUNCES

a new device for direct measurement of Single-phase KVA demand



TYPE IHE WATTHOUR THERMAL KVA DEMAND METER

This conventional bi-metallic thermal element is coupled in a unique way with a "resistance valve" to give a true measure of kva. See explanation in text at right.

You can now measure single-phase kva demand easily and economically with this new G-E meter.

A NOVEL APPLICATION of the *"direct-heat"* current-energized thermal element has made this possible. A resistor (controlled thermally by voltage) has been inserted in series with the negative torque spiral of the thermal element. Torque of the element, therefore, varies directly with line voltage as well as current. Since the torque of the thermal element is caused by the current and by the heating effect of the line voltage, operation of the meter is independent of phase relation (power factor). Thus it gives a true measure of kva.

OTHER DESIRABLE FEATURES of the IHE include a wide-limit watthour meter element. It is equally accurate at high and low loads. It has braking magnets die-cast in the frame for calibration stability. And, it has a relief gap that provides a controlled breakdown point.

Load curves, response times, thermal ratings, and other details are available in Bulletin GEC-504. Your nearest G-E representative will be glad to give you a copy. Or you can write to *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

661-45

MEASUREMENTS CORPORATION MODEL 80

STANDARD SIGNAL GENERATOR

2 to 400 MEGACYCLES

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

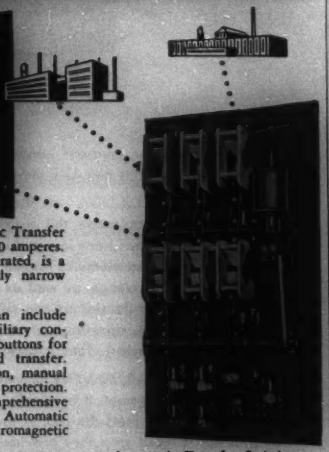
FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE 0.1 to 100,000 microvolts

OUTPUT IMPEDANCE 50 ohms

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

HEADQUARTERS FOR
AUTOMATIC
TRANSFER
SWITCHES



We can take care of almost any Automatic Transfer Switch requirement ranging from 5 to 1000 amperes. For example, Bulletin 906-105S, as illustrated, is a 300 ampere unit installed in a specially narrow panel for a distribution control center.

Standard features on control panels can include phase failure protection, indicating auxiliary contacts, engine starting contacts and push buttons for engine tests, reset to normal and load transfer. Special features include delayed operation, manual emergency handles, low frequency relay protection. Condensed Catalog No. 700 gives a comprehensive picture of our work along the line of Automatic Transfer Switches and complete Electromagnetic Control Panels.

If you require any type of automatic control, write us. Our 60 odd years of broad experience in the field of Electromagnetic Controls should be helpful.

Automatic Transfer Switches
Remote Control Switches
Contactors Relays
Specialized Electromagnetic Controls

We also manufacture a complete line of Solenoid Operated Valves for Automatic and Remote Control of Liquids and Gases.

ASCO Electro-Magnetic CONTROLS

Automatic Switch Co.

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INDUSTRIAL APPLICATION of ELECTRON TUBES

Papers and discussions presented at the AIEE Conference on Industrial Application of Electron Tubes, Buffalo, N.Y., April 1949. Sponsored by the AIEE Subcommittee on Electron Tubes of the Electronic Committee and the Subcommittee on Electronic Control of the Industrial Control Committee, jointly with the AIEE Niagara Frontier Section.
Price: $3.50.

and

AUTOMATIC CONTOURING CONTROL of MACHINE TOOLS

Papers presented at the AIEE Conference on Automatic Contouring for Machine Tools held during the AIEE Midwest General Meeting, Milwaukee, Wis., October 1948. Sponsored by the Machine Tool Subcommittee of the AIEE General Industry Applications Committee. The papers cover mechanical, electric, and hydraulic contouring devices, and combinations of these types, as applied to machine tools.
Price: $4.00 ($2.50 to AIEE members).

Orders for these publications should be sent to:

AIEE ORDER DEPARTMENT
33 West 39th Street
New York 18, N. Y.

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STACKPOLE

CARBON • GRAPHITE • MOLDED METAL

Engineering News

FIRST AID FOR A LOT OF CONTACT TROUBLES

Having trouble getting contacts for long life and low contact resistance on continued operations where heavy arcs exist, or under closed conditions? Then Stackpole Silver-Tungsten Contacts are probably the answer to your problem—whether it applies to a circuit breaker, motor controller, transformer protective device, aviation relay, contactor or similar equipment that requires an extremely durable contact.

TYPICAL STACKPOLE SILVER TUNGSTEN GRADES

Grade	Composition % Silver	Cross Breaking Strength Lbs. per Sq. in.	Hardness Rockwell Superficial	Density	Electrical Conductivity Ag = 100	Contact Resistance Estimated Ag = 100
FW56	70	57,000	15T75	12.0	75	120
FW49	50	82,000	30T56	13.2	55	150
FW41	35	108,000	30T72	14.6	45	200
FW34	32	110,000	30T76	14.7	40	250

Only a few standard types are available. Best results are obtained by laboratory testing of contact mixes containing different percentages of silver and graphite. These tests are made on the actual device under operating conditions—a service Stackpole gladly renders to makers of original electrical equipment. Write for details.

NEW! INEXPENSIVE 3 AMPERE SNAP SWITCHES

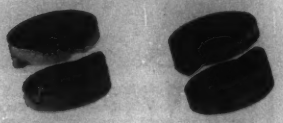
These sturdy little switches meet the need for units having sufficient current-carrying capacity for electrical toys, appliances and similar equipment. SS-26 is single-pole, single-throw and SS-26-1 is single-pole, double-throw. Both are rated at 3 amperes at 125 V. AC or 1 ampere at 125 V. DC. Both are Underwriters approved. Designed and constructed for long, dependable service, they are available at low cost. Samples on request to quantity users.

PUMP SHAFT MECHANICAL SEALS

Pump or compressor seals molded from suitable mixtures of carbon, graphite or carbon-graphite offer distinct advantages, for many applications. In contrast to the ordinary "packing type" seal, these molded Stackpole *mechanical* units seal the shaft tightly and *without any wearing surface bearing on it.* This prolongs shaft life while assuring greater operating efficiency. In addition, Stackpole molded seals are unexcelled for difficult applications where a tight seal must be maintained under high pressure conditions.

Mechanical seals can be molded to close tolerances and to a variety of shapes. As amply proved by Stackpole's broad experience, they are ideal for many different shaft sealing applications. Write, giving details of your application for specific recommendation.

WELDING OR BRAZING CARBON ELECTRODES that last 3 to 4 times as long



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More than a catalog, Stackpole Booklet 40 contains a wealth of data to help you evaluate the electrical, mechanical or chemical advantages of carbon, graphite or carbon-graphite on a long list of applications. Write for copy today on your company stationery.

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THE NEW MOLONEY HiperCore*

DISTRIBUTION TRANSFORMERS

*CORES MADE OF HIGH PERMEABILITY, ORIENTED, SILICON STEEL

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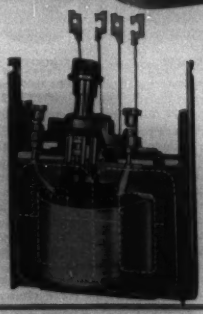

Dotted line in illustration at left, indicate position of core in assembled core-and-coil unit. After cores are wound, they are annealed, impregnated and then cut into pairs of U-shaped pieces. Two large U-shaped pieces are placed side by side, forming an inner and two outer core legs. Then the windings are placed over the inner core leg. Next, the two matching U-shaped pieces are placed into position to complete the magnetic circuits. A thermo-setting adhesive bonds the core faces together.

BETTER VOLTAGE REGULATION AT ALL LOADS

Development of the new Moloney HiperCore Transformer has made possible a reduction in transformer impedance, resulting in better voltage regulation. These wound core transformers, being smaller physically, have inherently lower impedance than transformers of conventional core design.

Better voltage regulation means better all-around system performance. Secondary voltage fluctuations, due to sudden or intermittent load changes, are reduced. Secondary voltages may be maintained at a higher level resulting in improved performance of the connected load.

In many installations emergency loading is controlled largely by transformer voltage regulation. Moloney HiperCore Distribution Transformers, having better regulation, can carry higher overloads with the same permissible voltage drop.

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GREATER SHORT-TIME OVERLOAD CAPACITY

Moloney HiperCore Transformers have improved short-time overload characteristics which provide better peak load performance and longer life. Reduced coil mass, achieved through use of oriented steel cores, together with the extensive use of cooling ducts, results in more rapid cooling of the windings and in a lower hottest-spot temperature gradient.

LIGHTER WEIGHT

The 30% to 35% higher flux carrying capacity of the oriented core steel used in HiperCore Transformers makes possible the use of smaller cores and windings, with consequent reductions in the weights of steel, copper, oil, and other materials. HiperCore Transformers weigh 15% to 30% less than transformers having cores made of hot rolled steel, making them easier to handle and install.

SMALLER SIZE

Since the higher flux carrying capacity of oriented steel permits the use of smaller cores and windings, smaller tanks can be used. Reductions in size range up to 30%. HiperCore Transformers take up less space on the pole, in the storeroom, and on the line truck.

SUPERIOR TAP CHANGER DESIGN

The "snap action" movement of the tap changer used on Moloney HiperCore Transformers assures positive pressure at all times. The handle is above the hot oil level and the dial can be read from the handhole opening. The body of the tap changer is made of high-impact-strength phenolic resin for high insulation and elimination of breakage. Use of high contact pressure and oversize contact surfaces insures low temperature rise and eliminates pitting or burning.

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THE UNIVERSAL CLAY PRODUCTS CO.
1563 EAST FIRST STREET SANDUSKY, OHIO

The QUICKEST way to supply 115V from a 230V Wiring System

Connect an Acme Electric Air Cooled transformer to the 230 volt power line to obtain a 115 volt circuit at the exact spot you need it. Acme Air Cooled transformers are built in sizes from 1/10th KVA to 50 KVA, single phase, all standard primary voltages up to 600 volts. All steel construction provides more capacity per pound, high efficiency, better performance. Write for Bulletin.

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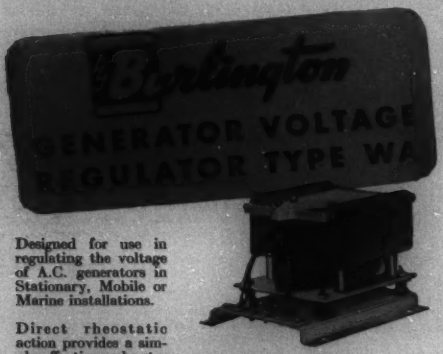
Acme Electric TRANSFORMERS



Designed for use in regulating the voltage of A.C. generators in Stationary, Mobile or Marine installations.

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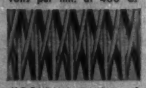
KOOLOHM layer winding turns cannot "swim" or short. Insulation has a dielectric strength of 350 volts per mil, at 400°C.



KOOLOHM interleaved winding—Resistors are available having negligible inductance, even at VHF.

Section of KOOLOHM wire with ceramic insulation removed to show contrast between bare and insulated wire. This flexible, heat-proof insulation is actually applied to the wire at a temperature of 1000°C.

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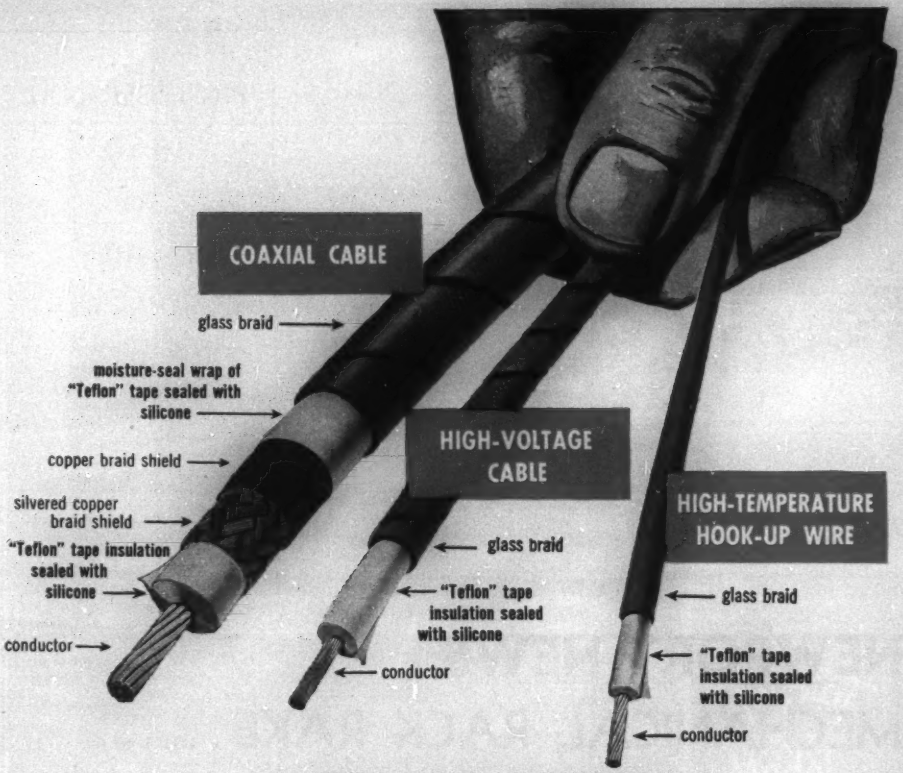

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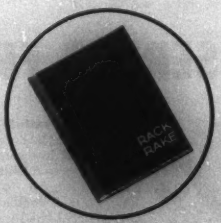

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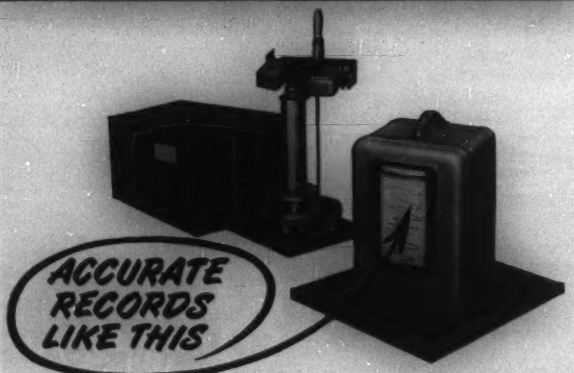
(*Continued from page 22A*)

are up to 75 per cent over former models; standard gear assemblies are designed to withstand a maximum load of 45 pound-inches and special designs are available which are capable of withstanding torques up to 200 pound-inches without mechanical failure. These actuators are especially suited for aircraft application. Additional information may be obtained by writing to the Electromechanical Division of the company.

Electronic Adjustable Speed Drive. A new fractional-horsepower Mot-O-Trol electronic adjustable-speed drive is available from Westinghouse Electric Corporation. The control starts, stops, and controls the speeds of one-eighth- to one-half-horsepower d-c motors, operated from single-phase 50/60-cycle 220/440-volt power sources. Armature control makes possible a speed range of 20 to 1 at constant torque. For further details, write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh, 30, Pa.

PHOTOELECTRIC RECORDER



can help solve your problems, too

Here the General Electric photoelectric recorder is being used with an electric tachometer to record minute variations in the speed of a motor under development for the textile industry. It is part of an experiment with a tensiometer aimed at achieving uniform "winding tension" for weaving bobbins. This should lead to greater production and better woven products. The G-E photoelectric recorder is playing a vital part in this development.

EXAMINE YOUR DEVELOPMENT AND PRODUCTION OPERATIONS—then consider the G-E recorder. It can help you solve many problems by supplying accurate, high-speed records of phenomena such as—

Current	Voltage	Temperature	Light	Thickness
Pressure	Strain	Air Flow	Vibration	Speed

Magnetic Flux—or almost *any other quantity that can be measured by an indicating instrument.*

EXTREMELY SENSITIVE—This versatile instrument comes in two basic forms, a deflection type using a pivoted or suspension-type measurement instrument, and a potentiometer type operating on the null-balance principle. Both types are sensitive far beyond the range of ordinary recording instruments.

HIGH-SPEED RESPONSE—The photoelectric balancing system rapidly moves the recording mechanism to follow exactly the deflection of the measuring instrument or null-balance detector. Yet, it imposes virtually no additional burden on the circuit.

WIDE RANGE OF CHART SPEEDS AND SENSITIVITIES—Chart speeds range from ½ inch per hour to 72 inches per minute. Response speeds can be as fast as ¼ second for full-scale deflection. And sensitivities can be obtained for values as low as 1.0 microampere full scale.

Full details on the other advantages of these instruments, plus operating principles, ratings, prices, etc. are contained in Bulletin GEC-254. Write for your copy today. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

660-158

General Electric Developments. General Electric has announced a new line of lifetime-lubricated, shaded-pole motors designed for operation in any position. Designated as Type *KSP*, the motors are available in either open or totally enclosed construction; ratings range from 25 milli-horsepower (1/40 horsepower) through 1/12 horsepower at 115 or 230 volts, 1,050 or 1,550 rpm, 60 cycles.

Another recent development at General Electric is an ION series of Hi-surge fuse links which will provide improved over-current protection where 10-ampere minimum fusing has been used previously. Available in 2-, 3-, 5-, and 8-ampere ratings for overcurrent protection, each of the new links also provides the same surge protection as a 10-ampere universal cable-type fuse.

Third new development at G-E is a unit-combination arrester and cutout, which combines the basic design features of the 9-kv hi-stroke arrester and the 7.8-kv 50-ampere flip-open cutout, to provide low-cost protection of conventional distribution transformers on rural lines rated 7,200/12,-470 and 7,620/13,200-volts grounded Y. Construction of the cutout permits a fuse link to be inserted in the wedge-type contacts from either side, while helical-wound springs retard side sway of contact arm and protect the link from vibration stresses. A built-in reserve of gas-evolving material compansates for erosion.

For further data write to the Apparatus Department, General Electric Company, Schenectady 5, N. Y.

Chance Connectors. The A. B. Chance Company, Centralia, Mo., has produced a new line of power connectors, terminals, and bus supports, such as tee, cross, stud, and ground connectors, couplers, reducers, elbows, tubing and plug terminals, and tubing and cable bus supports. Additional information on the new line may be had from the company.

Low-Cost Panelboard. The Trumbull Electric Manufacturing Company has designed a new panelboard designed to provide economical group and branch circuit control of lighting distribution for all industrial and commercial applications. The NTPR panelboard, available in six to 42 circuits, has a hot-molded phenolic section containing six complete circuits. An illustrated bulletin, *TEC-4*, which completely describes the panelboard, may be obtained by writing to The Trumbull Electric Manufacturing Company at Plainville, Conn.

Miniature Relay. Frame *181*, a box-like relay structure which offers maximum

(*Continued on page 46A*)

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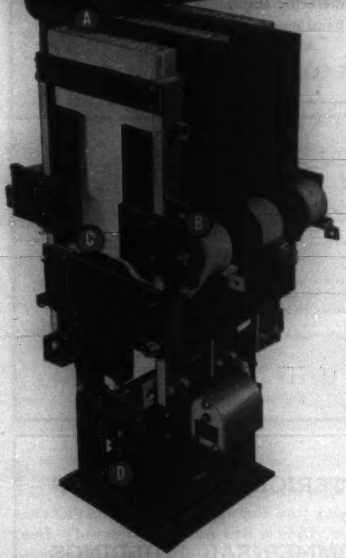
Increase Contact Life



FOR THE FIRST TIME a High Voltage Air Contactor with double break contacts and direct vertical action is now available! This design eliminates turning shafts, shaft bearings and flexible contact leads . . . cuts maintenance.

Contact life is increased! Movable contacts are self-aligning. Contact inserts of arc resistant alloy assure clean, long wearing contact surfaces.

Measuring only 15 x 25 x 38 inches, the Type 256 Air Contactor combines three methods of arc extinction to permit its compact design. 1. Double break contacts cut arc voltage in half. 2. Dual continuous duty blowout coils snuff out low current arcs, speed the upward movement of higher current arcs. 3. Special arc chutes stretch arcs both horizontally and vertically.

Built for general alternating current motor starting applications, it has a simple, rugged design which makes it especially adaptable to heavy duty applications requiring frequent starting, inching, reversing, plugging, or dynamic braking.

The Type 256 Contactor is available in ratings of 200 and 400 amperes at 2500 volts, 200 amperes at 5000 volts.

The Allis-Chalmers line of High Voltage Starters has been expanded to include the Type 256 Contactor. Utilize the advantages of this completely tested unit. Call your nearby A-C Sales Office or send coupon today.

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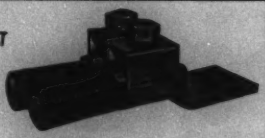

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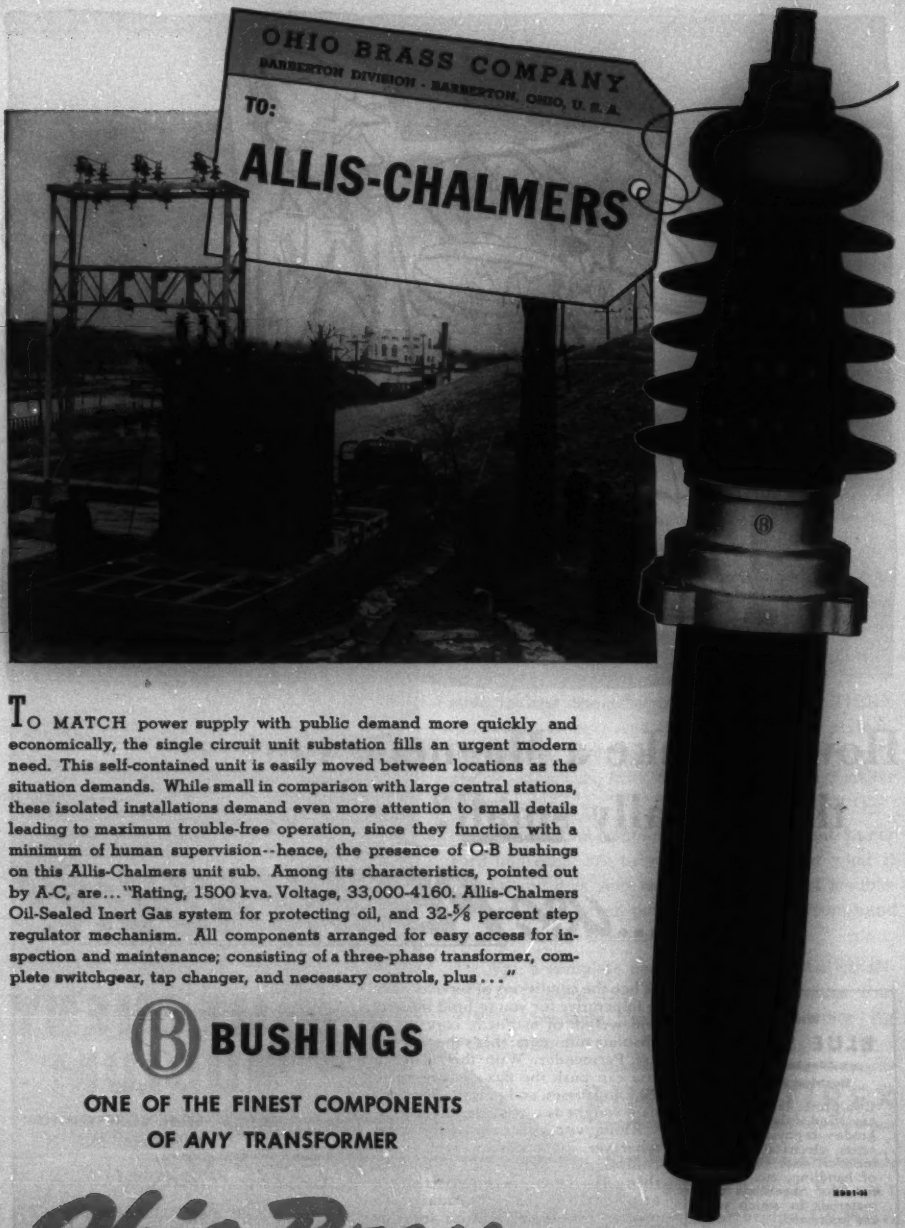

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ONE OF THE FINEST COMPONENTS OF ANY TRANSFORMER

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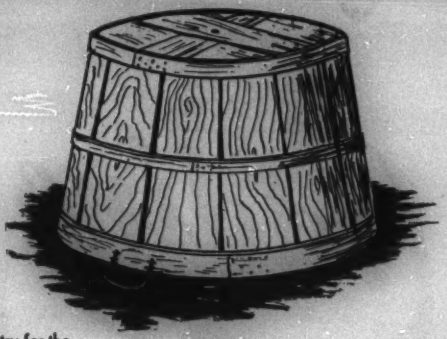

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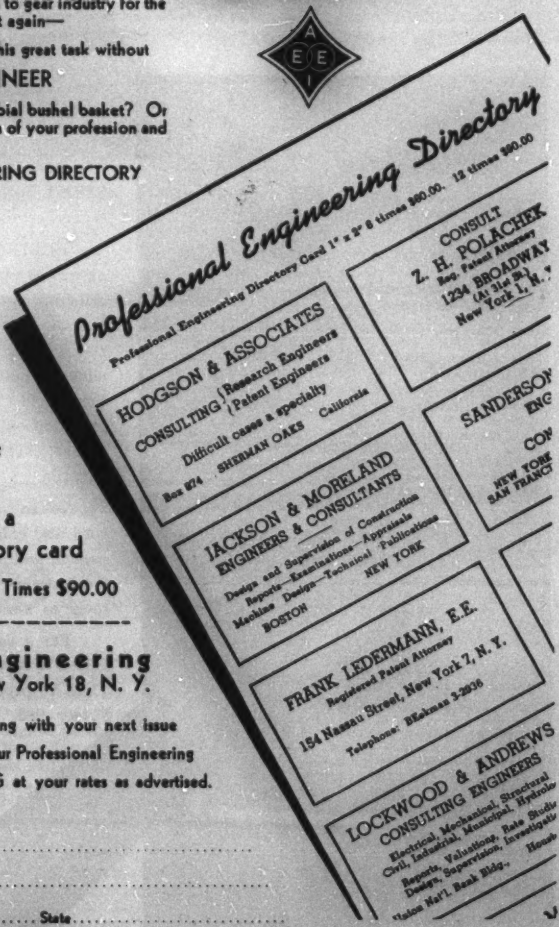

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This General Electric power connector can simplify your inventory by 63% to 83%

Five General Electric power connectors of the type shown above will handle *all* the 22 conductor sizes listed in the table*. Compare this feature with other brands that usually *require a different connector for each conductor size.* You'll immediately realize how much G-E connectors can cut your stock costs by reducing the number of connectors required.

Here are other ways you can SAVE by using G-E connectors.

SAVE TIME—No more stock room safaris hunting for odd-size connectors. When you stock General Electric connectors, you stock fewer connectors. Also, you save time in ordering—you don't have to search through bulky catalogs looking for connectors that are seldom used and are a nuisance to order, besides taking up valuable stock space. G-E connectors are easy to order for the simple reason that you don't have to order so many varieties.

SAVE SPACE—Less stock room space required when you use G-E connectors because fewer connectors are needed to take care of the same range of conductor sizes that you're using now.

SAVE MONEY—When you use G-E connectors you reduce stock storage costs, and you save valuable time in ordering.

CHECK THESE ADDITIONAL FEATURES OF GENERAL ELECTRIC CONNECTORS

SILVER CONTACT SURFACES are a *standard* feature on *all* G-E connectors for use with copper conductors—at no extra cost. This eliminates oxidation problems, assures lower contact losses and longer life.

SERRATED CONTACT SURFACES give extremely high pull-out strength and a permanent, high-conductivity joint that will resist vibration and give positive pressure on the cable at all times.

NON-CORRODIBLE HARDWARE is of high-strength bronze alloy that gives tight and trouble-free service. G-E connectors will not twist, distort, or season crack.

INTERLOCKING SIDES confine the strands of the cable within the conductor enclosure, thus obtaining full advantage of the cable's current-carrying capacity.

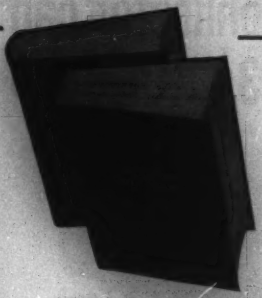
Place an order today with your G-E sales representative and start realizing the many benefits to be gained by using this new line of General Electric connectors. Also, write for a copy of bulletin GEC-400 that contains 38 pages of valuable information on these new connectors, and see for yourself how easy they are to order. Write to *Apparatus Department, Section K 856-51, General Electric Company, Schenectady 5, New York.*

*General Electric connectors come in a wide range of sizes and types—straight, tee, block, angle, parallel, expansion, ground, and many others. See bulletin GEC-400 for the complete line.

Conductor size	General Electric Catalog No.	Connector Mfg. A	Connector Mfg. B	Connector Mfg. C	Connector Mfg. D
1/0	6151174–9 One G-E connector replaces 6, stock is reduced 83⅓ %	√	√	√	√
2/0		√	√	√	√
3/0		√	√	√	√
4/0		√	√	√	√
250		√	√	√	√
300		√	√	√	√
350	6151174–59	√	√	√	√
400		√	None	√	None
500		√	√	√	√
600		None	None	√	√
½ IPS		√	None	√	√
700	6151174–88	None	None	√	None
750		None	None	√	√
800		None	None	√	√
1000		None	None	√	√
3/4 IPS		√	√	√	√
1250	6151174–118 One G-E connector replaces 3, stock is reduced 66⅔%	None	None	√	√
1500		None	None	√	√
1 IPS		None	None	√	√
1750	61151174–148	None	None	√	√
2000		None	None	√	√
1¼ IPS		None	None	None	√
	Only 5 G-E connectors for ALL 22 conductor sizes	11 connectors for 11 cond. sizes. No connectors available for 11 conductor sizes	9 connectors for 9 cond. sizes. No connectors available for 11 conductor sizes	21 different connectors for 21 cond. sizes	20 different connectors for 20 cond. sizes

√ Indicates a different connector.

GENERAL ELECTRIC



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Volume II—COMMUNICATION—ELECTRONICS will be ready soon. Because the electronics field has advanced so extensively in past years, it has been necessary to increase many portions of the book to include current developments. In particular, frequency modulation and all the pulse techniques in both the communication and radar fields appear in the volume for the first time.

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(*Continued from page 38A*)

resistance to mechanical stress for low-voltage d-c application, has been announced by Struthers-Dunn. A completely balanced armature minimizes false contact operation under shock and vibration; 50 per cent more coil volume than existing types of comparable size assures positive operation of strong leaf spring contacts. Bulletin *2610*, which further describes these relays, will be sent on request to Struthers-Dunn, Inc., 150 N. 13th Street, Philadelphia 7, Pa.

Portable Potentiometer. Designed especially for use in testing corrosion along pipe lines, cables, and other buried metal structures, Leeds and Northrup's new portable potentiometer makes it possible to obtain fast, accurate readings over the wide range encountered when investigating galvanic and electrolytic action. Total range of the instrument is zero to 4.1 volts, measurable in millivolt steps. This range is subdivided into 12 different steps, some of which overlap. An electromotive force reversing key makes it possible to measure opposite polarities without changing leads. Standardization is not affected by switching the reversing key or changing ranges. Current is provided by flashlight batteries and bindingposts are provided for connection to any external 6-volt d-c source when needed. The Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa., will furnish any additional details.

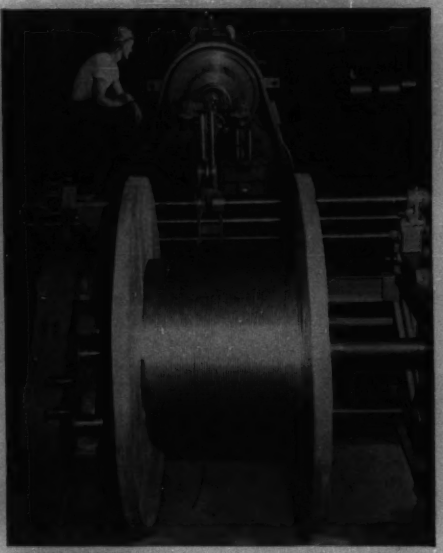
Two-Bolt Connector. W. N. Matthews Corporation, 3850 Delor Street, St. Louis, Mo., has announced development of the *642* Matthews Uniclamp, a new 2-bolt connector, which makes possible the same type of connections on conductors as small as six solid, which previously have been available on conductors of 1/0 and above. The connector is cold-forged of copper, and is applicable to the making of copper to copper; copper to aluminum; and aluminum to aluminum connections. Further information is available from the company.

Ceramic Capacitors. Wafer-thin multisection capacitors designed for bypass and coupling applications, have been introduced by the Sprague Electric Company. Known as Sprague BULPLATE ceramic capacitors, the new units are furnished with either multiple capacitor sections alone or in combination with printed wiring, shielding, and other printed details. They are covered with moisture-proof coating that protects them against short-circuiting to other components as well as severe conditions of humidity, temperature, and vibration. A typical BULPLATE 1 1/2-inch long by 5/8-inch wide (exclusive of leads) may combine five capacitors of 0.002; 0.001; 0.00015 and two of 0.005 microfarad, or other values as desired. Sprague Engineering Bulletin Number *601A* giving full details of the capacitors will be sent upon request to The Sprague Electric Company at North Adams, Mass.

(*Continued on page 52A*)

From start . . . to finish . . .

AT KAISER ALUMINUM'S Newark, Ohio plant, the production of high quality Kaiser Aluminum conductor starts in the remelt department. Here high purity pig from its own reduction plants is remelted and cast into 99.5% purity ingots 6" square and 12' long. These pass through a series of automatic break-down and finishing mills to become rod ready for wire drawing.



ROD IS DRAWN into wire on the most modern equipment in the electrical conductor industry. High speed cable stranders, manned by skilled personnel, produce the finished conductor, which has been tested at every step by modern methods and equipment. Result of this completely integrated production control is pictured below—aluminum conductor of unsurpassed quality!

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As important as the high quality of Kaiser Aluminum Conductor is the consistently dependable deliveries assured by Kaiser Aluminum's centrally located Newark, Ohio plant.

Early delivery schedules of all sizes of ACSR and all-aluminum conductor are now open. For immediate information, contact any sales office listed below.

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VITREOUS-ENAMEL COVERING
Winding is rigidly held in place and protected from damage by Ohmite special vitreous enamel.

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"Hot spots" and resultant failures are prevented by the resistance winding's unsurpassed uniformity.

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Unaffected by cold, heat, fumes, or high humidity, its core provides a strong base for winding.

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Lengths range from 1¼ inch to 4 inches, corresponding to ratings of 30 to 75 watts.

INTEGRAL MOUNTING BRACKETS
Distribute heat more evenly throughout resistor and conduct heat away quickly.

...PACK HIGHER WATTAGE INTO LESS SPACE

Because of their compact design, Ohmite Thin Type Resistors have a higher wattage rating per unit of space. They provide all the time-proven superiority of conventional Ohmite vitreous-enamel resistors—giving you a compact unit you can depend upon. Available in four types—all only ⅛ inch thick by 1 inch wide—in five lengths and a wide range of resistance values.

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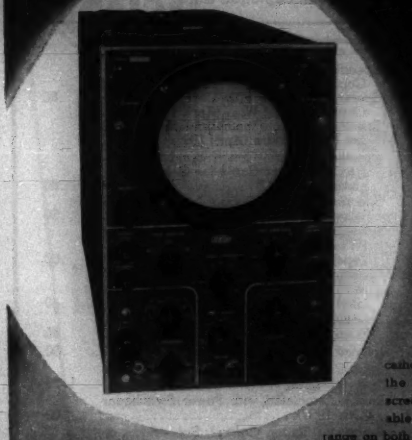

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NEVER BEFORE HAVE THESE FEATURES BEEN COMBINED IN ONE INSTRUMENT AND OFFERED AT SUCH LOW COST!

HIGH-GAIN AMPLIFIERS X- AND Y-AXES

Sensitivity: X-Axis, 50 millivolts rms per inch (AC and DC). Y-Axis, 10 millivolts rms per inch (AC and DC).

Frequency Response: DC amp. X and Y Axes, 0-100,000 cps within 10%; 0-300,000 cps within 50%. AC amp. X and Y Axes, 20-100,000 cps within 10%; 20-300,000 cps within 50%.

No pattern "hop" even with sudden changes in signal level. Excellent stability and minimum microphonics and drift. Provision for applying signals directly to deflection plates.

STABILIZED SYNCHRONIZATION

Sync limiting provided on recurrent sweep, so that sweep length and synchronization are maintained as signal level varies.

EXPANSION OF DETAILS

Due to available deflection of over 4 times full-screen diameter on both X and Y Axes, performance equivalent to that of a 20-inch cathode-ray tube is possible, with the high resolution of a 5-inch screen. Full positioning is available over this entire expanded range on both axes.

RECURRENT AND DRIVEN SWEEPS

Variable from 2 to 30,000 cps. Sweep speeds faster than 0.75 inch/μsec. with fully expanded time base. Provision incorporated for sweeps of 10 seconds and slower through the connection of external capacitors at front-panel terminals. Sync amplifier with sync-polarity selection is provided.

INTENSITY MODULATION

Z-Axis input terminal on front panel is capacitively coupled to grid of cathode-ray tube. 15 volts peak will blank trace fully at normal intensity.

INCREASED ACCELERATING POTENTIAL

Du Mont Type 5CP-A Cathode-Ray Tube in the Type 304-H is operated at overall accelerating potential of 3000 volts, facilitating use of long-persistence screens to take full advantage of low-frequency recurrent sweeps, fast-driven sweeps, and DC amplifiers. Type 304, a lower-price version, is also available, operating at an overall accelerating potential of 1780 volts.

ADDITIONAL FEATURES

An engraved, permanently-mounted c[alibra]ted scale greatly facilitates quantit[ative] measurements. Mu-Metal magnetic shield af[fo]rds maximum protection of cathode-r[ay] tube from effects of external magnetic fiel[ds]. Du Mont Type 2501 Bezel permits attachme[nt] of such accessories as Du Mont Types 271-[A] or 214-A Oscillograph-Record Cameras.

MECHANICAL DETAILS

Height, 13½"; Width, 8⅜"; Depth, 1[8]. Weight, 50 lbs. Housed in metal cabinet w[ith] gray wrinkle finish. Panel reverse etched white on gray.

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This oscillograph has undergone a most rig[id] field test both in our own laboratories and again in selected laboratories and institu[tions] throughout the country. In a great va[ri]ety of applications, every feature has been given a thorough workout. The Type 304-H is not a new instrument of unknown quality but definitely an oscillograph of TRIED AND PROVED EXCELLENCE.

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Type 304-H, $307.50. Type 304, $285.00.

Full details of performance and applications are contained in a 12-page bulletin obtainable by writing to . . .

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Standards on electric machinery and apparatus chiefly devoted to defining terms, conditions, and limits which characterize behavior, with special reference to acceptance tests.

A discount of 50 per cent, on single copies is allowed to Institute members except as noted. Such discount is not applicable on extra copies unless ordered for other members.

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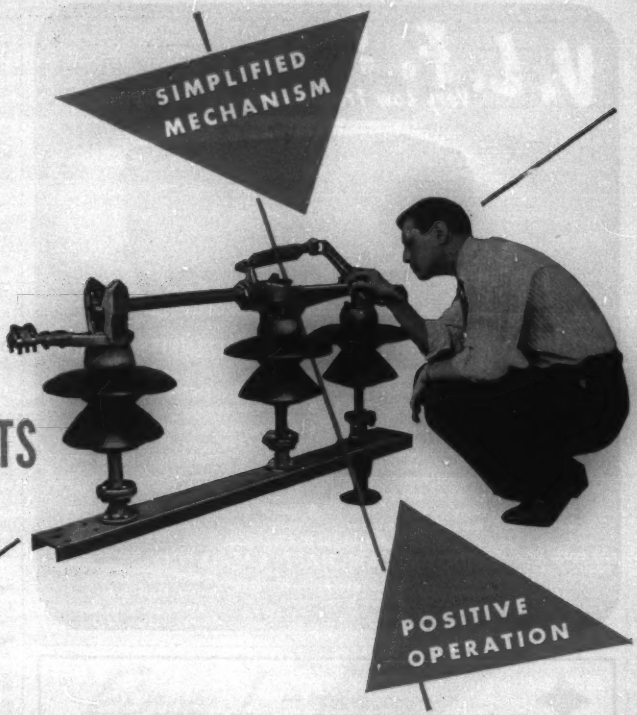
12-49

TYPE RF DISCONNECTS



A COMPLETE LINE

. . . from 7.5 to 230 kv. For further details of these disconnects see your nearest G-E sales representative or write for bulletin GEA-4980 that pictorially shows the features of this switch in the new multi-exposure photo technique. *Apparatus Department, General Electric Company, Schenectady 5, New York.*

BLADE MECHANISM **has no cams or braids, is of simplified, easy-maintenance construction. Antifriction bearings are used on all main moving parts. This makes the switch exceptionally easy to operate at all times, especially under "glaze storm" and other severe weather conditions.**

SILVER-TO-SILVER **contact surfaces assure positive contact at all times and eliminate oxidation troubles that often cause annoying maintenance. You get power flow with no losses. This gives you a switch that doesn't overheat.**

STURDY CONTACTS **have U-shaped "fingers" with silver contact surfaces that are backed by noncurrent-carrying, stainless-steel springs. The housing, a strong casting, protects the fingers from dirt and ice.**

BASE **is a sturdy channel that will remain rigid even though the switch is put through high stresses under abnormal operating conditions. Also, Type RF switches are easy to line up on structures.**

GENERAL ELECTRIC

853-4

V. L. F. !
Very Low Frequencies covered by the . . .
STODDART NM-10A
RADIO INTERFERENCE AND FIELD INTENSITY METER
STODDART AIRCRAFT RADIO CO.

Report on GUIDING PRINCIPLES for DIELECTRIC TESTS

(Published for comment and criticism)

The service record of electric equipment depends largely upon the performance of its insulation, and it has long been the practice to test new insulation at a voltage appreciably greater than its rated operating voltage. Dielectric test voltages should be chosen to result in good operating performance and satisfactory life. The purpose of this report (AIEE No. 51, September, 1949) therefore, is (1) to present a survey of the overvoltages encountered in service, (2) to review existing test values and practices in present standards, (3) to propose guiding principles for the selection of dielectric test values, and (4) to investigate other types of testing to determine their latent usefulness and the desirability of standardization.

\+ \+ \+

Proposed Standard for AUTOMATIC CIRCUIT RECLOSERS for DISTRIBUTION SYSTEMS

(Proposed for one year trial use)

This standard (AIEE No. 50, September, 1949) applies to all single or multipole a-c automatic circuit reclosers rated from 1,500 to 15,000 volts. The work of preparing this standard was carried out by the Working Group on Automatic Circuit Reclosers under the Circuit Breaker Subcommittee of the AIEE Committee on Switchgear.

There is no charge for these publications. Orders should be sent to:

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street
New York 18, N. Y.

12-49

(Continued from page 46A)

TRADE LITERATURE

Industrial Capacitor Slide Film. "Sittin' and Savin'," a color-sound slide film designed specifically for the cost-conscious industrial plant engineer, has been produced by the General Electric Company. The film demonstrates how the average capacitor installation results in a 30 to 60 per cent investment return on every dollar spent. Prints of the film are now available and showing may be arranged for interested parties through General Electric sales engineers or General Electric district offices throughout the United States.

Heptafluorobutyric Acid. The Minnesota Mining and Manufacturing Company, New Products Division, Saint Paul 6, Minn., has issued a new booklet on Heptafluorobutyric Acid, a completely fluorinated reactive fluorochemical. Most of the information in the booklet has been previously presented in papers at the 116th National Meeting of the American Chemical Society at Atlantic City, N. J., in September 1949. Research quantities of heptafluorobutyric acid are available, and samples will be supplied upon request, as well as copies of the booklet.

"Case of the Metal That Was Caught." Design and operation of the Allis-Chalmers metal detector, an electronic sentry designed to safeguard nonmetallic products, are described in a new 20-page bulletin released by the company. The metal detector spots all kinds of metal in particles as small as 0.039 inch in diameter, regardless of how deeply imbedded in the material they may be. It is being used in the plastics, food, confectionery, paper, rubber, textile, tobacco, ceramics, grain, and other industries. Copies of "Case of the Metal That Was Caught," Bulletin *14B7217A*, are available upon request from Allis-Chalmers Manufacturing Company, South 70th Street, Milwaukee, Wis.

Cathode-Ray Oscillographs. The Allen B. Du Mont Laboratories, Inc., Instrument Division, 1000 Main Avenue, Clifton, N. J., has issued a pamphlet which deals with the recently developed Du Mont Types *304* and *304-H* cathode-ray oscillographs, which replace the well-known Type *208-B*. Copies of the booklet are available upon request to the company.

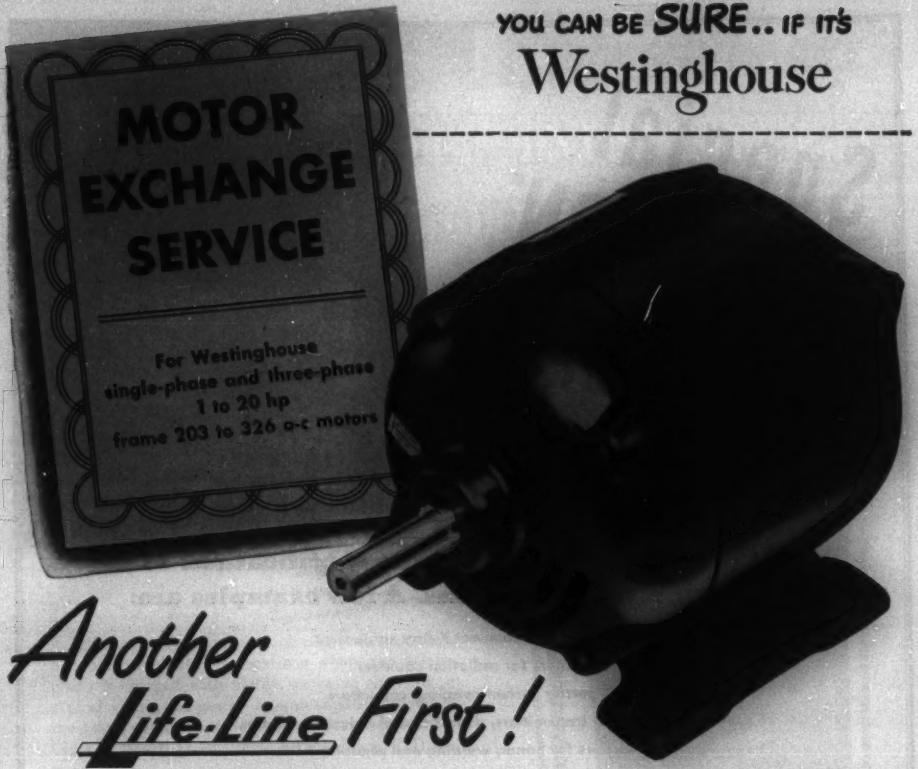
Chance Tips. Volume *11*, Number *3* of "Chance Tips," published by the A. B. Chance Company, Centralia, Mo., discusses the design and performance of hot tap clamps. The bulletin may be obtained by writing to the company.

Rockbestos Publications. "The Story of an Insulation," (a trans-vision booklet) and "Rockbestos AVC Cuts Cable Costs," are two recent publications issued by the Rockbestos Products Corporation, to aid electrical engineers working in low-voltage

(Continued on page 56A)

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



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Since February, 1949, Life-Line motors have offered you the broadest exchange plan in industry. All 1 to 20-hp, single-phase and three-phase a-c motors in frame 203 to 326 are included. No other manufacturer of motors—large or small—provides exchange service that compares in scope to this new Life-Line Motor Exchange Service.

120 Westinghouse exchange points assure you rush motor replacement service anywhere in the United States. Replacement motors, covered by this plan, are in stock, ready to be speeded to you at any time.

And what's more, if a motor fails during warranty period, it may be exchanged *free* for a motor of identical rating. The *exchange price*, beyond warranty, *is not dependent on the time in service . . . one year, five years or ten years.*

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Complete details on the Life-Line Exchange Service—lists of exchange points and motor ratings covered—are given in the new booklet SM-5243. Get your copy today from your nearby Westinghouse representative or write direct to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Penna. J-21533

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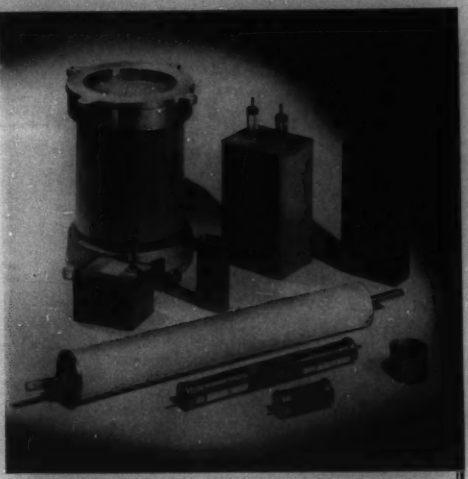

* Plastic Film Dielectric Capacitors

We manufacture capacitors to specifications for many unusual applications. A few examples are:

- High voltage filter capacitors for compact X-Ray equipment
- Ultra high resistance capacitors for radiation counters
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In addition to our capacitors, we manufacture a standard line and build special high voltage, low current power supplies.

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Type 780 KBF-1, Frame 100, closed position. Note provision for straight-thru conduit connections.

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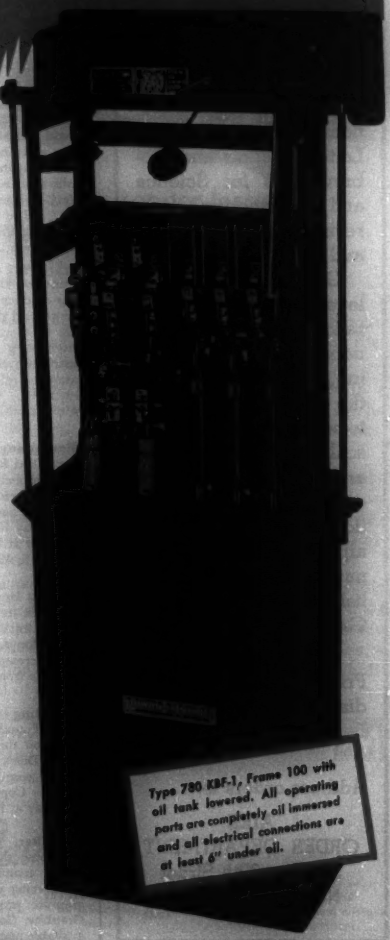
Rowan type 780 KBF-1 Combination Starters, consist of heavy duty magnetic contactors of the clapper type, giving high speed closing and opening with positive roll and wipe action, magnetic overload relays with inverse time element by means of Rowan AIR SEAL dashpots, each relay is individually tested and calibrated. Safety disconnect switch is of the contactor type with quick make and break mechanism and equipped with Rowan time tested AIR SEAL fuses—top and tank are mechanically interlocked with safety disconnect handle for positive safety with provision for padlocking operating handle in the OFF position.

Complete information available in Bulletin form.



Type 780 KBF-1, Frame 100 with oil tank lowered. All operating parts are completely oil immersed and all electrical connections are at least 6" under oil.

ROWAN CONTROL

American Standard LETTER SYMBOLS for ELECTRICAL QUANTITIES

This new American Standard (Z10.5—June 1949) prepared by a subcommittee of the Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering, is a revision of ASA Z10g1 and AIEE 17g1.

General principles of letter symbol standardization, a typographical notation for distinguishing, in the equations of the printed page, between the symbols for scalar, complex (phasor), and vector quantities are given, as well as tabulations of the symbols in alphabetical order of the names of quantities, English letter symbols, and Greek letter symbols.

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(Continued from page 52A)

wiring. Both are available upon request to the company at New Haven 4, Conn.

Telemetering Systems. A 20-page, illustrated bulletin, *GEA-5233*, which describes the newest General Electric telemetering equipment for electric power distribution and industrial applications, has been released. The bulletin gives detailed information on the frequency-type, torque-balance-type, and photoelectric-type telemeters manufactured by the company. Copies are available from the General Electric Company, Schenectady 5, N. Y.

"Welding Notes for Engineers." Published twice a month by the Eutectic Welding Alloys Corporation, 40 Worth Street, New York 13, N. Y., "Welding Notes for Engineers" is a bulletin devoted to unusual stories of salvage by welding and solutions of difficult fabrication problems. Copies are available from the company.

Lightning Arresters. The Electric Service and Manufacturing Company has issued a booklet entitled "Impulse Spark-over and Discharge Voltage Characteristics of Lightning Arresters and Their Coordination with Impulse Withstand Voltage Characteristics of Transformer Insulation." The booklet may be obtained by writing to the company at 17th and Cambria Streets, Philadelphia 32, Pa.

"Outdoor Oil Circuit Breakers." Outdoor oil circuit breakers designed for use on a-c general distribution service where circuit breakers of 50,000 and 100,000 kva interrupting capacity are required, are described and illustrated in a 38-page catalogue released by Roller-Smith, Bethlehem, Pa. Copies of catalogue *3640* may be obtained by writing to the company.

"Everything in Radio and Electronics." The Allied Radio Corporation of Chicago has published its new 1950 196-page catalogue, covering equipment for "Everything in Radio and Electronics." The buying guide may be obtained by writing to the company at 833 West Jackson Boulevard, Chicago 7, Ill.

Die-Less Duplicating. The Di-Arco system of die-less duplicating is described in a 40-page catalog published by the O'Neil-Irwin Manufacturing Company, Lake City, Minn., creators of the system. Copies are available from the company.

Threading of Stainless. The Cooper Alloy Foundry Company has issued a folder on threading of stainless steel, entitled "Don't Fear Threading of Stainless." Actual case studies, other data are presented. Copies may be obtained from the company at Hillside 5, N. J.

Graphitar. A 64-page wire-bound catalog describing the properties, chemical resistance, manufacturing limitations, and engineering uses of Graphitar, a carbon-graphite product of The United States Graphite Company, Saginaw, Mich., is available upon request to the company.

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Master Test Code for Resistance Measurement. May 1949. Price: $0.80.

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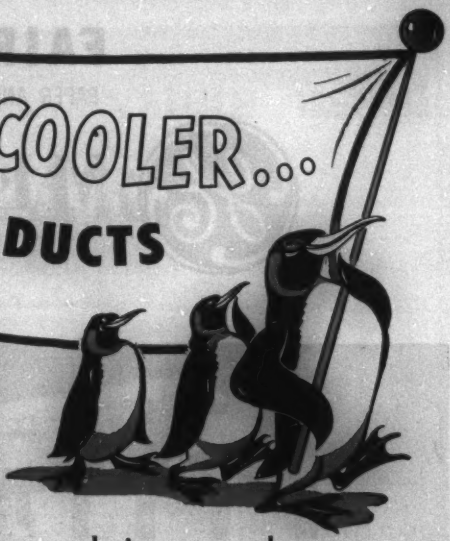

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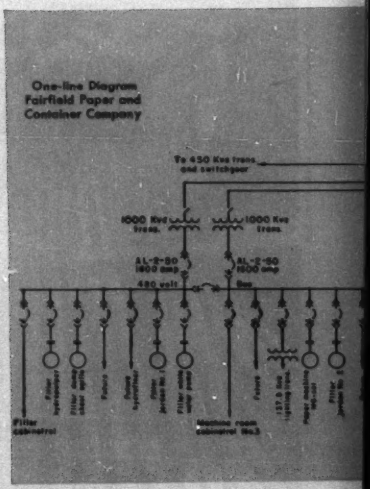

G-E Cabinetrol units provide centralized control for the liner stock system. Unit controls motors, valves, agitators, etc. Ammeters record load carried by hydrapulper and hydrofiner. Four other Cabinetrol units are used throughout the mill.

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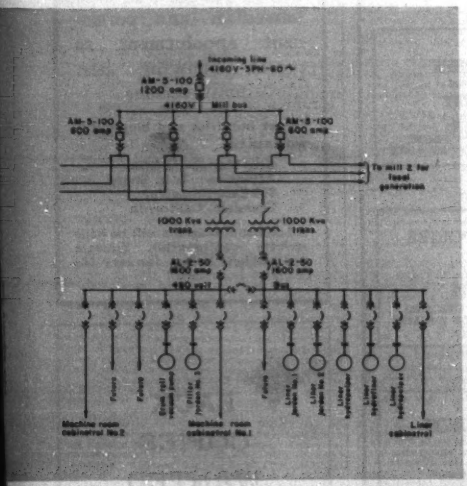
secondary-selective system using

SWITCHGEAR

continuity of service



At the new Fairfield Paper and Container Co. installation General Electric metal-clad switchgear receives the incoming 4160-volt power and distributes it to 4-1000 kva transformers for step-down to 480 volts. G-E metal-enclosed switchgear handles the 480-volt power through air circuit breakers of the drawout type. In general, all motors rated 60 hp and above are served by an individual breaker. Five Cabinetrol units are fed by air circuit breakers. Note that costly secondary feeders are short.

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12-49

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For help and situations wanted, $0.60 per line for AIEE members, others $1.00. Sale and purchase of used machinery, etc., $1.50 per line, minimum 3 lines, maximum 30 lines, not available to dealers. Address orders to: Classified Section, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

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Apply by letter addressed to the key number and mail to New York Office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription rate of $3.50 per quarter or $12 per annum, payable in advance.

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ELECTRICAL OR ELECTRONIC ENGINEER, 30–35, graduate, with at least five years' design and development experience on electrical and electro-mechanical instruments and control systems, to design and develop electrical indicating instruments in the aeronautical and industrial fields. Salary, $4500–$5000 a year. Location, northern New Jersey. Y-2896(a).

COMMERCIAL ENGINEER, 30–35, electrical graduate, or mechanical graduate with equivalent electrical knowledge from training and experience, with field sales service experience, including installation and service of products, repairs, engineering changes, etc. After two or three months sales training, will be responsible for technical sales correspondence, estimating for pricing and for quotations to customers, preparing sales data for use by sales, advertising or service departments, etc. Salary open. Location, Connecticut Y-2919.

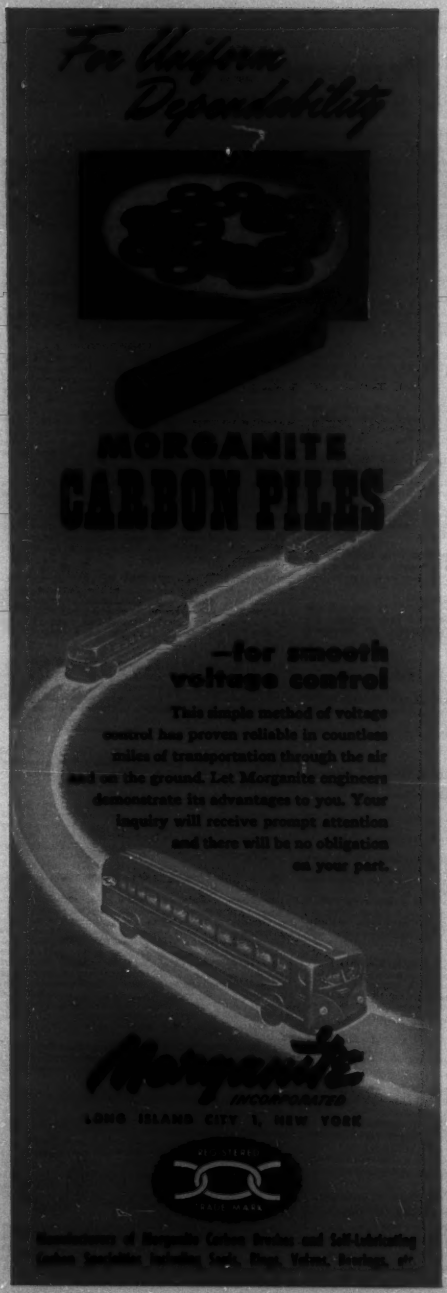
ASSISTANT TO SALES MANAGER, 35–40, graduate electrical engineer, or mechanical engineer with equivalent electrical knowledge from training and experience. Experience in the sale and service of electrical machinery, equipment or instruments. Must have sales management experience, including administration of a technical sales office, sales engineering experience, selling industrial electrical and mechanical equipment, field service experience, preferably as a service engineer. Will assist the sales manager in the administration of the engineering sales and district sales offices, including sales correspondence, cost estimating, preparing technical and sales data for miscellaneous sales and advertising use. Must be free and willing to travel. Salary open. Location, Connecticut. Y-2920(b).

ELECTRONIC ENGINEER with at least five years' photo-electric cell, miniature cyro experience for design, development and application in industrial control field Salary, $6500–$7500 a year. Y-2929(a).

POWER AND STEAM MAINTENANCE ENGINEER, 32–40, graduate, electrical and/or steam engineering major, with ten years' experience in maintenance of power plant equipment, such as boilers, turbines and auxiliaries, steam and electric distribution systems, to take complete charge of maintenance and construction in connection with a 30,000 KW electric system and a 650,000 lbs. per hour steam system. Will supervise work of about 100 men, including millwrights, electricians, pipers, welders, etc. Salary open. Location, New Hampshire. Y-2967.

ELECTRICAL ENGINEER with at least two years' experience in testing DC motors and generators to be service engineer supervising brush tests on diesel electrics on railroads. Must be free to travel extensively. Salary, $4000–$5000 a year. Location, New York Metropolitan Area. Y-2969.

NOTE: Closing date for material to be set in the classified advertising column, as well as cancellations for running ads, must be received not later than the first of the month preceding issue; i.e., August first for September issue.


For Uniform Dependability
MORGANITE
CARBON PILES
—for smooth voltage control
This simple method of voltage control has proven reliable in countless miles of transportation through the air and on the ground. Let Morganite engineers demonstrate its advantages to you. Your inquiry will receive prompt attention and there will be no obligation on your part.
Morganite
INCORPORATED
LONG ISLAND CITY 1, NEW YORK
Manufacturers of Morganite Carbon Brushes and Self-Lubricating Carbon Specialties including Seals, Rings, Vanes, Bearings, etc.

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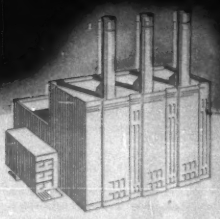
YOU CAN BE **SURE**.. IF IT'S

Westinghouse



Instruments "Check-Rein" 240,000 Horsepower!

When the power load builds up and up, it's Westinghouse Instruments that give the tip-off! Another generator is called into action—steady voltage flows over the network . . .

This is a familiar routine at the new B. C. Cobb Station, owned by Consumers Power Company. This modern steam electric generating plant, located on the shores of Lake Muskegon, Michigan, has a rated capacity of 180,000 kw, or 240,000 horsepower. Westinghouse Instruments have been standardized on here—keep a vigilant watch over power that is generated at 14,400 volts, then transformed to 22,000, 44,000 and 140,000 volts.

Serving as the "eyes" for this massive power system calls for instrument reliability to the nth degree. We believe Westinghouse Instruments meet this challenge. *You can be sure* of the complete line of Westinghouse Instruments—from calling the turn on a microamp. to keeping a "check-rein" on all the concentrated horsepower America's genius can devise.

Westinghouse Instrument Specialists are available in the field for consultation. Call your nearest Westinghouse office, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-40379

Westinghouse INSTRUMENTS

Cole Electric Co.

8439 Steller Drive — Culver City, Calif.

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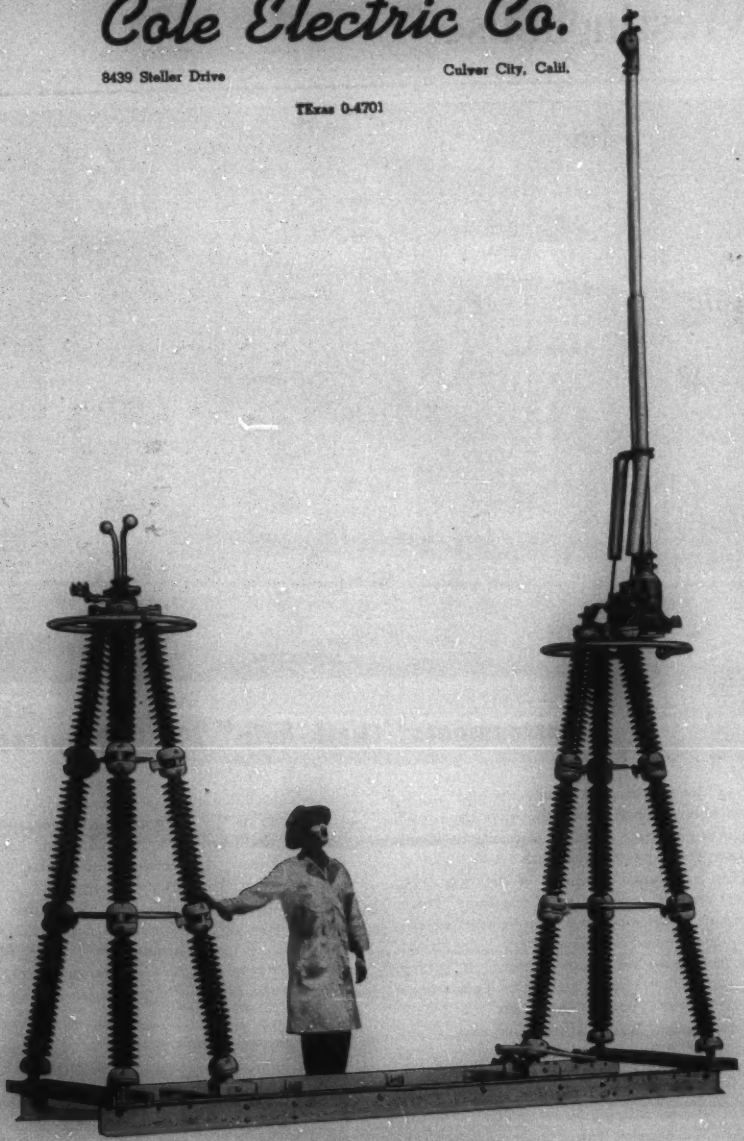
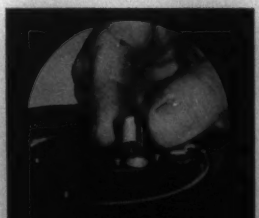
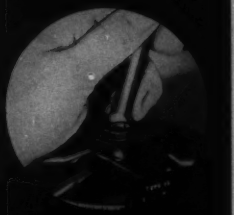


AIR BREAK DISCONNECTING SWITCH
230,000 Volts—1200 Amperes—Type MO-2
Vertical Break—Three Pole, Single Throw
Group Operated
(One pole shown)



NO tools needed to change the VARIAC brush. A twist of the cartridge-like holder and it and the brush come out immediately.



For changing to behind-the-panel or to table mounting the brush, radiator, collar, etc. are not disturbed. Just the shaft, dial and knob, as a unit, are removed.

Moulded barriers between terminals eliminate possibility of short-circuits. Both screw and solder terminals provided. Voltages across terminals clearly indicated on moulded terminal board.

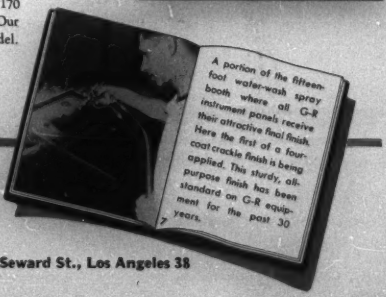
Look closely into *all* the advantages of VARIAC VOLTAGE CONTROLS

- **EXCELLENT REGULATION** — less than ¾% at line voltage and less than 3% of line at ½ line voltage. There is very little change in output voltage under varying loads with the VARIAC*
- **TOROIDIAL CONSTRUCTION** — voltage change is directly proportional to dial rotation over the complete output range
- **MACHINE-WOUND COILS** — insure maximum uniformity in lay and tension of windings (and a toroidial winding machine for wire of these sizes is a neat machine to design!)
- **ADVANCED BRUSH CONSTRUCTION** — coil spring maintains uniform brush pressure under all conditions of brush wear; very low inertia of sprung weight in moving part results in less wear under vibration, and eliminates bounce; NO TOOLS needed to change brushes
- **READILY REMOVABLE SHAFT** — for reversing to table or panel mounting — requires no disassembly of radiators, collars, etc.
- **KEYED SHAFTS** — on larger models requiring greater torque, insure permanent line-up of shaft and radiator; especially important in ganging
- **NO PIGTAIL CONNECTIONS**
- **SAFE TERMINALS** — for either screw or solder connections — clearly marked in output voltages
- **PRESSURE CONTACTS** in the VARIAC do not depend upon mechanical properties of insulating materials

VARIACS are manufactured and sold in standard units or assemblies to control from 170 to 24,700 va. There is a VARIAC to fit almost any a-c voltage-control problem. Our engineering department will be glad to assist you in selecting the most suitable model.

*VARIAC *is a registered trade name*

Write for the new VARIAC BULLETIN


A portion of the fifteen-foot water-wash spray booth where all G-R instrument panels receive their attractive final finish. Here the first of a four-coat crackle finish is being applied. This sturdy, all-purpose finish has been standard on G-R equipment for the past 30 years.

GR

GENERAL RADIO COMPANY

Cambridge 39, Massachusetts

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Another RCA First...
5786
5770
5762
5771
RCA-5786 . . . 1.5-kw input up to 160 Mc
Fil. Power—138 watts . . . No comparable pure-tungsten type
RCA-5762 . . . 5.5-kw input up to 110 Mc
Fil. Power—365 watts . . . No comparable pure-tungsten type
RCA-5771 . . . 60-kw input up to 25 Mc
Fil. Power—1273 watts . . . saving *—70%
RCA-5671 . . . 100-kw input up to 10 Mc
Fil. Power—3.1 kw . . . saving *—60%
RCA-5770 . . . 150-kw input up to 20 Mc
Fil. Power—3.1 kw . . . saving *—60%
Plate inputs are for class C service without amplitude modulation.
*Over comparable pure-tungsten type.

. . . the economy of thoriated-tungsten filaments and improved cooling in high-power tubes

Here is unparalleled tube value . . .

Five new RCA tubes, ranging in power input from 1.5- to 150-kw, and successfully utilizing economical thoriated-tungsten filaments which offer marked savings in filament power and the cost of associated power equipment.

Five tubes with proved features of previous similar types. Two—the 5762 and 5786—have efficient newly designed radiators that permit the use of less expensive blowers.

Five tubes with improved internal constructions that contribute to their more efficient operation and longer service life.

These five new RCA tube types are "musts" for designers of broadcast, communications and industrial electronic equipment where design and operating economies alike are important considerations.

Forced-air-cooled assemblies and water-jacket assemblies are available for most RCA power tubes.

RCA Application Engineers are ready to consult with you on the application of these improved tubes and accessories to your specific designs. For complete technical information covering the types in which you are interested, write RCA, Commercial Engineering, Section 39LR, Harrison, New Jersey.

THE FOUNTAINHEAD OF MODERN TUBE DEVELOPMENT IS RCA

TUBE DEPARTMENT
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